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PHYTOPATHOLOGY

VOLUME 17 NUMBER 5

MAY, 1927

PREVENTION OF SEEDLING DISEASES OF SUGAR BEETS

G. H. Coons and Dewey Stewart

Each year the root diseases of sugar beets (*Beta vulgaris* L.) cause considerable loss. Practically every state where sugar beets are grown has submitted to the Plant Disease Survey of the U. S. Department of Agriculture reports of damage from damping-off and other forms of root disease. These losses range from a trace to 20–25 per cent of the crop, but the occurrence of the trouble is sporadic and seems correlated with unfavorable growing conditions in the spring. Due to variation in severity from year to year and due to greater emphasis given in the literature to the other more striking diseases of the sugar beet, losses from this source have largely been overlooked. The common cause of failure to get a stand in fungous attack, which gives rise to the so-called "seedling diseases" of sugar beets. A general discussion of the nature of these diseases and their importance under Michigan conditions has been given by Coons (1), who emphasizes the significance of the diseases contracted in the seedling stage in the general root rot development of half-grown and mature beets.

The actual importance of seedling diseases can best be judged by taking into consideration the enormous differences in stands which are obtained in various fields planted with the same seed stocks, under fairly normal conditions. These fields range from full stands to practical failures of stands. The majority of fields show about 75 per cent of the possible stand, and there are many fields on the border line of profit and loss. In Michigan, where this study was made, the seedling diseases and the resultant root-rot constitute the most important sugar beet disease problem. The greatest losses occur on the heavier and the muck soils, and especially on those with poor natural drainage.

Sugar beets are commonly grown in a four-year rotation, as experience has taught the hazard of following beets with beets. In many sections, the use of beets after clover or alfalfa is a common practice. Observations of the writers, extending over many seasons, seem to indicate that, in general, better stands of beets are obtained when beets follow corn instead of legumes.

Indeed, in one section of Michigan, the farmers within a decade have adopted in large measure the latter practice. Clover, vetch, and alfalfa roots show many Rhizoctonia lesions and it is the writers' belief that these crops, as well as potatoes, serve to intensify Rhizoctonia infestation, while with grain cropping the Rhizoctonia infestation is lessened. In Michigan, the sugar beet crop is planted over a period ranging from April 20 to June 20. The standard practice is followed of sowing heavily (15 to 18 pounds per acre) in drill rows, 20 to 24 inches apart, and later thinning to approximately 12 inches in the row. The heavy seeding is an attempt to allow for the very uncertain sprouting of the seed and the heavy reduction of stand by disease. It is obvious that the crowding in the row and the weakening of the plants greatly favors the development of diseases of this type. Cultivation is advised as soon as rows can be followed. The young plants are allowed to grow with no attempt at thinning until decision can be made as to the quality of the stand. If soil and weather conditions have been favorable and cultivation timely, a stand profitable to work generally results. A stand giving promise of at least 7 tons per acre is necessary because of the heavy labor charges involved in the crop. On the other hand, heavy rains, or rainy periods of long duration, low temperature, poor seed, and insufficient drainage all operate to produce poor stands. In such cases, the fields are reworked and either replanted to beets or to some other crop. There have been seasons when as much as 25 per cent of the acreage planted failed to show a profitable stand and was replanted or abandoned. It is obvious that the matter of a good stand is fundamental to success with the crop, and the tests reported in this paper are concerned with seed treatment as affecting stand.

PREVIOUS WORK ON SEEDLING DISEASES OF SUGAR BEETS

Root disease, black rot, or black leg has long been known as a sugar beet disease problem. In the old literature, insects and soil factors were believed responsible. Hellriegel (7) first called attention to the fungous and bacterial factors involved when by a 20-hour soaking of the seed in 1 per cent carbolic acid solution he lessened the root-rot. He attributed this effect to the disinfection of the seed ball. The work of Wimmer (16), Wilfarth (17), and Karlson (9) substantiated this viewpoint. Frank (6) and Krüger (10) later demonstrated the seriousness of *Phoma betae*, but the tendency of nearly all of the older research work was to look upon root disease as an indication of some defect in cultural conditions rather than a parasitic relation influenced by environmental conditions.

Duggar and Stewart (4), in 1901, proved that *Corticium vagum* B. and C. *solani* Burt. (called by them *Rhizoctonia*) was capable of killing sugar beet

seedlings. Pammel (11), Selby (15), and Duggar (3) had previously reported *Rhizoctonia* as causing root-rot in fields of mature beets.

European literature for many years has had numerous, more or less intensive studies on sugar-beet root diseases called "Wurzelbrand." In a series of reports between 1906 and 1911, Peters and his associates (12) went over the voluminous literature and from this and their own experiments concluded that *Pythium debaryanum* Hesse, *Phoma betae* (Oud.) Fr., *Aphanomyces laevis* de By. were the organisms concerned in the production of seedling diseases of sugar beets in Germany. The German investigators were unable to produce damping-off with *Rhizoctonia violacea* Tul.

In 1915, Edson (5) working at Madison, Wisconsin, found that *Phoma betae*, *Pythium debaryanum* and *Rhizoctonia* spp. as well as an organism which he later named *Rheosporangium aphanidermatum*,[1] were the principal organisms concerned in the seedling diseases of sugar beets in the United States. Each organism produced a high percentage of diseased plants when introduced into the seed bed. Edson also found *Phoma betae* present in all lots of seed balls from Europe or America examined, thus confirming the previous results of Peters.

Although *Phoma* is constantly being introduced into sugar beet fields, Pool and McKay (13) have shown that it does not live from year to year in the soil except on fragments of sugar beet tissues. However *Rhizoctonia*, and the Phycomycetes, *Pythium debaryanum*, *Aphanomyces laevis*, and *Pythium aphanidermatum*, are common soil organisms (Jensen, 8; Drechsler, 2) widely distributed in nature.

The problem of controlling sugar beet seedling diseases is, therefore, concerned with the seed-borne fungus, *Phoma betae*, and the numerous soil inhabiting fungi capable of attacking beets. It is obvious that since non-infested soil cannot be found for use with disinfected seed, seed treatment at best can be only partially effective.

Besides this difficulty, it has been found by several experimenters that treatment of seed to eliminate *Phoma betae* was not possible. Edson (5), in an attempt to free seeds from *Phoma betae*, tried three different treatments: (*a*) strong solution of hydrochloric acid, (*b*) concentrated sulphuric acid for one hour, and (*c*) two per cent formaldehyde solution. Each treatment was used for periods sufficient to injure the seedling without materially reducing the subsequent development of *Phoma*.

However, Peters' method of pasteurization at 60° C. for ten minutes on two successive days gave one Phoma-diseased plant in about three or four hundred. Edson (5, p. 138) states that this method is not practical for field use, as the germination is reduced. In 1924, Miss Rumbold (14)

[1] Now known as *Pythium aphanidermatum* (Edson) Fitzp.

reported favorable results in sugar beet seed disinfection using formaldehyde and steam in a sort of combination pasteurization and disinfection system. This method has not come into general use.

DESCRIPTION OF SEEDLING DISEASES

The diseases of sugar beet seedlings considered in this investigation are those commonly known as black root, "root disease," and damping-off. These names, more or less descriptive of the diseased seedlings, are used loosely in the literature to apply to death of seedlings from one cause or another. By field examination it is not ordinarily possible to assign the root rot to a particular organism, but culture work is necessary for determination of the causal factor. In one type of disease the seedling shows a browning and blackening of the hypocotyl and root. The discoloration usually shows above the surface of the ground before the seedling topples over. The killing may be fairly rapid or take place so slowly that the seedling seems almost ready to outgrow the disease. Plants are frequently found with hypocotyl completely blackened as far as the cotyledon, which remains turgid and green. Examination of such plants shows the vascular region as the only part not affected. The general impression one has from the examination of such a seedling is that the attack has been made by a moderately rapidly growing organism, which produces a dry type of decay.

Contrasted with this type of disease is one in which rapid wilting occurs, usually unaccompanied by marked discoloration. Such plants have a brown decayed region in the root, and the central vascular region is discolored far in advance of the external lesions. The lesions have a water-soaked appearance as compared with the dry, black lesions characteristic of the first type of attack. Twenty-four hours after the first indications of wilting the seedling is almost completely decayed.

In a third type of seedling disease, which is not so distinctive in appearance as the others, the color of the young leaves gives the first indication of disease. The leaves may be merely deeper green in color, but occasionally they are blue green. Associated with this sign, one finds often a lemon-yellow color of the stem. The seedlings grow slowly and, in general, show evidence of malnutrition. On removing the seedling from the soil, the taproot is found decayed at the tip and the rootlets above the decayed region are developing, apparently attempting to replace the primary root. No doubt, many of the seedlings thus affected develop into marketable mature beets, but of poor type.

It is hazardous to assign particular organisms to these three disease aspects. As has been said, the beet seedling shows but slight distinctiveness in reaction to the various organisms, and many of the infections are un-

doubtedly mixed infections. The organism obtained by culturing a diseased seedling, especially if this is done tardily, may not be the primary organism concerned. Furthermore, the type of medium used for plating influences strongly the fungous growth which develops from the decayed seedlings, and may even determine the flora which develops.

Generally our results have shown that *Phoma betae* was chiefly associated with the first type of disease, *Pythium* spp. with the second type, and *Rhizoctonia* spp. with the third type.

Mention should also be made of a type of injury often overlooked but exceedingly common. This is the rotting or damping-off of the seedling almost immediately upon its emergence from the seed ball. Such seed balls behave as if non-viable, while in reality the sprout germinates and the little seedling is killed immediately upon emergence. Under wet soil conditions this may be the most common form of attack. From such material *Pythium* spp. have commonly been isolated, but *Phoma betae* is doubtless also responsible.

SEED INFESTATION BY PHOMA

As has been indicated, many workers have demonstrated the presence of *Phoma betae* in commercial sugar beet seed. We were desirous of determining whether this fungus could be eliminated by more care in seed production. Investigation was made using samples of seed from the special stocks of seed produced in the sugar beet breeding work of Mr. E. E. Down, of the U. S. Department of Agriculture. These samples were from isolated breeding plots in the vicinity of Lansing, and the seed had been grown from carefully selected, entirely sound roots which had been carried through the winter under excellent conditions. The seeds were hand-cleaned and represented seed grown with as much care as possible.

Fifty seed balls each of 15 samples were planted in sterile sand in moist chambers. As the seedlings began to die following germination, examination for *Phoma* was made. *Phoma betae* was found in 10 samples of the 15.

This test indicates the very high degree of infestation by *Phoma betae* which exists in seed stocks, since even the careful handling, as in seed breeding work, failed to eliminate it.

METHODS

In preliminary work, the sugar beet seed balls were treated with various disinfectants in both liquid and dry form. Large moist chambers with absorbent paper were used, but it was found that the seedlings soon became covered with Alternarias and Mucors. When certain chemicals such as mercury bichloride were used, these leached from the seeds and showed

harmful effects on the roots. When moist sand was substituted for the paper, the seedlings died after a few days, due to excessive humidity within the chamber. The substitution of tall battery jars to get rid of the excess humidity factor was only partly successful. Our experience led us to the opinion that the small germinator was of doubtful value for the purpose of this investigation.

Accordingly, our tests, for the most part, were carried on in the greenhouse, growing the plants in an ordinary greenhouse bench. The preliminary tests had indicated that a partial control for *Phoma betae* and other fungi could be expected with certain chemicals. Tests with soil were chosen because this would give opportunity to determine the value of the various treatments not only as seed disinfectants but as protective agents against organisms arising from a soil source as well.

The bed used was 34 inches wide and 6 inches deep. The rows were 3 inches apart, and in the first test 50 seed balls were planted 1 inch deep in each row. In all the subsequent tests, 30 seed balls were planted in a row at uniform depth by means of a simple planting device. A narrow strip of wood containing 30 holes 1 inch apart was placed across the leveled bed, a seed ball was placed in each hole and this was forced one inch below the surface by means of a plunger.

The sugar beet seed used in these greenhouse experiments was all from the same bag, and was American-grown seed obtained through the courtesy of the Holland-St. Louis Sugar Co. Samples of average sized seed balls were counted out, preliminary to any treatment, in an attempt to insure as nearly uniform a number of germs per row as possible, and to prevent any unconscious selection of seed balls on the basis of size. Each test was done in duplicate, the bed being divided into two sections. Every third row was used as a check row. The diseased seedlings were removed after the counts were taken. Daily records were taken and these continued for from three weeks to a month. The diseased seedlings were cultured on cornmeal agar plates following 1–2-minute immersion in $HgCl_2$, 1–1000, and a rinse in sterile water unless otherwise indicated. The fungi developing were determined by microscopic examination.

Several complicating factors must be taken into account in experiments with sugar beet seeds. It must be borne in mind that the so-called sugar beet seed, the beet ball, is a cluster of embryos enclosed in the ovary wall along with remnants of the flower parts. The beet ball may contain from one to five or even more germs and close inspection is necessary to determine the number. The sorting of seed balls to a definite number of germs is not a practicable measure; accordingly, when 50 seed balls are planted, there will be considerable range in the number of seedlings emerging.

Then, too, the pathogens attacking beets spread from plant to plant, and the development of disease in a seedling may lead rather promptly to heavy loss of neighboring plants. Another complicating factor is the variation in the rate of emergence of the different sprouts. The germination of sugar beets planted at a uniform depth and given uniform watering stretches over a two-weeks period. The daily record taken from experimental rows shows a variation from day to day because some seedlings are lost by disease, and new seedlings are constantly coming up during the first part of the experimental period. In the records given in this paper we have summarized the daily readings to obtain a total of seedlings emerging and have made a similar summing up of the number of diseased seedlings found. On the last day of the test each row was counted, and this count checked, to determine the final stand. This stand has been compared with an assumed stand, such as would have been obtained from seed balls having two viable germs per ball under conditions when fungous attack was not a factor. We arrived at this figure as a fair normal to form a basis for judgment by many tests with average sized seed balls in sterile sand and sterile soil, after disinfecting the seed with various mercury disinfectants. The mean of many of these seed treatments showed approximately 1,000 seedlings from 500 seed balls.

EXPERIMENT I

Following the laboratory tests in germinators, various chemical treatments were carried on in the greenhouse, using a bench containing muck soil. This muck soil has been used for about two years for various vegetable crops, especially celery. The various treatments employed and the plan of the experiment is given in table 1 and illustrated in figure 1. This table shows the results obtained after a 23-day period. The last two columns show a ranking of the best treatments based (*a*) upon freedom from seedling disease and (*b*) upon stand.

It will be noted that the average germination of the check rows in this experiment was 55.5 ± 2.32. The average number of diseased seedlings was 32 ± 1.47. It will be noted that in spite of the variation in germination arising from beet balls of different sizes, as has been mentioned, these checks have not shown a very great range. Similarly the amount of damping-off which has occurred has fallen rather closely within the mean. It was not thought desirable to apply biometric analyses to other figures in the tables, since the results for the most part are so very outstanding. It seems safe to assume that we may expect a proportionate variation between the rows in the various treatments as is shown by the checks. It must be borne in mind, however, that where damping-off fungi occur in a clump of seedlings, the pathogens are likely to advance from seedling to seedling until

TABLE 1.—*Comparison of various sugar beet seed treatments on muck soil; 50 seed balls planted per row. Record taken over a 23-day period following germination*

Treatment	Number of seedlings emerging		Number of diseased seedlings		Per cent diseased		Per cent of "ideal stand"[h]		Averages		Rank based upon	
	Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand[h]	Freedom from disease	Stand
Check	63		33		52		30		52	30		
Copper sulphate and lime,[a] 50–50; dust, in excess	112	112	29	21	26	18	83	81	22	82	4	3
Copper carbonate,[b] 50 per cent; dust, in excess	99	89	44	6	44	6	45	83	25	64	6	6
Check	74	41	39	28	52	68	35	13	60	24		
Seed-O-San[c]	72	107	33	68	45	63	39	39	54	39		
Mercury bichloride, 1–1000; one hour soaking	93	93	10	24	10	25	83	69	18	76	3	4
Check	59	60	38	42	64	70	21	18	67	20		
Formaldehyde, 1–240; 30 min. soaking	55	46	28	29	50	63	27	17	57	22		
Chlorophol,[d] 1–400; one hour soaking	121	113	19	17	15	15	102	96	15	99	2	1
Check	69	59	27	36	39	61	42	23	50	33		
Kalimat[e]	75	84	43	45	57	53	42	39	55	41		
Pythal,[f] 0.25 per cent; one hour soaking	96	98	15	10	15	10	81	88	13	85	1	2
Check	51	36	28	16	54	44	23	20	49	22		
Nickel carbonate; dust, in excess	73	83	58	59	79	71	15	22	75	19		
Copper carbonate,[g] 18 per cent; dust, in excess	93	91	18	23	19	25	75	68	22	72	5	5
Check	47	53	34	30	72	56	13	23	64	18		
Average of checks	55.5 ± 2.32		32 ± 1.47									

[a] Copper sulphate-lime dust was a mixture consisting of equal parts of copper sulphate (dehydrated) and hydrated lime. This and other dusts used in these tests were applied "in excess," *i.e.*, all that would be carried by the seed. Application was made by shaking vigorously in a closed container for a few minutes.

[b] Copper carbonate, 50 per cent, was furnished by the Dow Chemical Co., Midland, Michigan. This was the ordinary C. P. compound containing approximately 50 per cent metallic copper and was not finely ground. It did not adhere well.

[c] Seed-O-San is an organic mercury compound furnished by Mr. M. O. Reiche, Chicago, Ill., and was applied, in excess, as a dust.

[d] Chlorophol is an organic mercury compound furnished by Mr. M. O. Reiche, Chicago, Ill., and was used as a 0.25 per cent solution for one hour.

[e] Kalimat is a proprietary compound containing formaldehyde furnished by the Chicago Process Co., Chicago, Ill.

[f] Pythal is an organic mercury compound containing phenol sold by the Chicago Process Co., Chicago, and was used as a 0.25 per cent solution for one hour.

[g] Copper carbonate, 18 per cent, was furnished by the Corona Chemical Co., Milwaukee, Wisconsin, and contained gypsum as its chief diluent. The analysis furnished by the company indicates an approximate metallic copper content of 18 per cent. It is sold under the trade name "Copper-carb." This dust adheres well and treated beet seed were conspicuously gray-blue.

[h] Based upon a normal stand of 50 seedlings per row.

TABLE 2.—*Summary of tests of various sugar beet seed treatments on muck soil; 50 seed balls planted per row. Record taken over a period of 19 days*

Treatment	Number of seedlings emerging		Number of diseased seedlings		Per cent diseased		Per cent of "ideal stand"		Averages		Rank based upon	
	Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
Check	63		33		52		30		52	30		
Copper sulphate and lime, 50–50; dust, in excess	112	112	29	21	26	18	83	81	22	82	4	3
Copper carbonate, 50 per cent; dust, in excess	99	89	44	6	44	6	45	83	25	64	6	6
Check	74	41	39	28	52	68	35	13	60	24		
Seed-O-San	72	107	33	68	45	63	39	39	54	39		
Mercury bichloride, 1–1000; one hour soaking	93	93	10	24	10	25	83	69	18	76	3	4
Check	59	60	38	42	64	70	21	18	67	20		
Formaldehyde, 1–240; 30 min. soaking	55	46	28	29	50	63	27	17	57	22		
Chlorophol, 1–400; one hour soaking	121	113	19	17	15	15	102	96	15	99	2	1
Check	69	59	27	36	39	61	42	23	50	33		
Kalimat	75	84	43	45	57	53	42	39	55	41		
Pythal, 0.25 per cent; one hour soaking	96	98	15	10	15	10	81	88	13	85	1	2
Check	51	36	28	16	54	44	23	20	49	22		
Nickel carbonate; dust, in excess	73	83	58	59	79	71	15	22	75	19		
Copper carbonate, 18 per cent; dust, in excess	93	91	18	23	19	25	75	68	22	72	5	5
Check	47	53	34	30	72	56	13	23	64	18		
Average of checks	55.5 ± 2.32		32 ± 1.47									

one hour.

[g] Copper carbonate, 18 per cent, was furnished by the Corona Chemical Co., Milwaukee, Wisconsin, and contained gypsum as its chief diluent. The analysis furnished by the company indicates an approximate metallic copper content of 18 per cent. It is sold under the trade name "Copper-carb." This dust adheres well and treated beet seed were conspicuously gray-blue.

[h] Based upon combined results of series A and B. [i] Based upon average of checks.

TABLE 2.—*Summary of tests of various sugar beet seed treatments on muck soil; 50 seed balls planted per row. Record taken over a period of 19 days*

No.	Treatment	Number of seedlings emerging		Number of diseased seedlings[d]		Per cent diseased		Per cent of "ideal stand"		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
I	Check	28	27	13	8	46	29	25	31	37.5	28.0	3	5
II	Small seed balls[a]	18	14	3	3	16	21	25	15	19.0	20.0		
III	Large seed balls[a]	54	38	22	15	40	39	50	33	39.5	41.5		
IV	Check	27	19	12	10	44	52	25	15	48.0	20.0		
V	Furfural,[b] 3 per cent	35	38	14	10	40	36	28	40	38.0	34.0		
VI	Furfural,[b] 1 per cent	30	27	11	15	36	55	33	18	44.5	25.5		
VII	Check	30	21	15	13	50	61	25	13	55.5	17.0		
VIII	Copper sulphate and lime dust	41	39	9	15	21	38	53	37	29.5	45.0	5	3
IX	Copper carbonate, 50 per dust	44	41	14	18	31	43	46	37	37.0	41.5		4
X	Check	36	33	13	16	36	48	38	28	42.0	33.0		
XI	Copper carbonate, 18 per dust	53	54	18	7	33	13	60	71	23.0	65.5	4	2
XII	Semesan;[c] dust	57	53	4	4	7	7	80	73	7.0	76.5	1	1
XIII	Check	35	28	9	12	25	42	43	26	33.5	34.5		
XIV	Large seed balls plus hydrated lime	29	30	10	9	34	30	28	28	32.0	28.0		
XV	Small seed balls plus hydrated lime	15	17	3	2	20	11	25	20	15.5	22.5	2	
XVI	Check	34	22	14	20	41	90	33	0	65.5	16.5		
XVII	Check		24		21		87		3				
	Average of checks	28 ± 1.02		13.5 ± 0.70									

[a] Commercial seed was passed over a series of fine mesh to remove dust and abortive seeds. It was then separated by means of a slightly coarser screen (4 mm. mesh) into two classes, large and small seed. The small seed consisted largely of single germ seed balls; the large seed consisted of seed balls of 3 to 5 germs with a few 2-germ seed balls.

[b] Furfural was obtained through the courtesy of the Miner Laboratory, Chicago, Ill., and was used as a soaking treatment at the two concentrations indicated after preliminary tests in germinators.

[c] Semesan was furnished by E. I. du Pont de Nemours and Co., Wilmington, Del., and was recommended for use as a solution, or as a dust. Its active ingredient is an organic mercury compound. The analysis as given by the company is hydroxymercurichlorophenol sulfate 30 per cent, inert material 70 per cent. The active ingredient is readily soluble in the slightly alkaline solution which is formed as a result of the wetting of the components of the mixture. It is characteristic of the Semesan solution to be cloudy and to deposit a small amount of inert material in the bottom of the container. Semesan was used unless otherwise noted as a dust treatment "in excess." The dust has excellent adherent qualities, and dusted seed is conspicuously gray-white in appearance, and feels slightly greasy to the touch.

[d] Each diseased seedling was treated with $HgCl_2$, 1–1000, for 1–2 minutes and rinsed in sterile water before planting on cornmeal agar. In determining the organism, part of the growth was examined under the microscope. No distinction was made between *Pythium* and its close relatives. The following organisms were isolated from diseased seedlings in the groups indicated by number: I, III, V, IX, and XVI, *Pythium*; II, XI, and XII, *Pythium* and bacteria; IV, *Pythium* and *Roscllina*; VI, *Pythium* and *Sordaria*; VII and XIII, *Pythium* and *Fusarium*; VIII, *Pythium* and *Alternaria*; X, *Pythium* and *Aspergillus*; XIV, *Aspergillus* and *Cephalothecium*; XV, bacteria.

a considerable number of adjacent plants are affected. This is the probable explanation of erratic figures found in some of the succeeding tables.

As is clearly brought out by the two columns of table 1 in which the best of the treatments are ranked, nearly all of them were better than the checks, with the exception of the formaldehyde and the Kalimat (which contains formaldehyde as its active ingredient). Chlorophol, Pythal, and mercury bichloride, 1–1000, gave the greatest reduction in disease along with a high total germination. It is very evident that in disinfecting value the mercury compounds must be given first rank. The copper dust treatments gave an increase in germination over the check and a decrease in the percentage of diseased seedlings. Copper carbonate, 50 per cent dust, gave a poorer stand than copper carbonate, 18 per cent. The first mentioned compound was not ground to the same fineness as the 18 per cent mixture. The

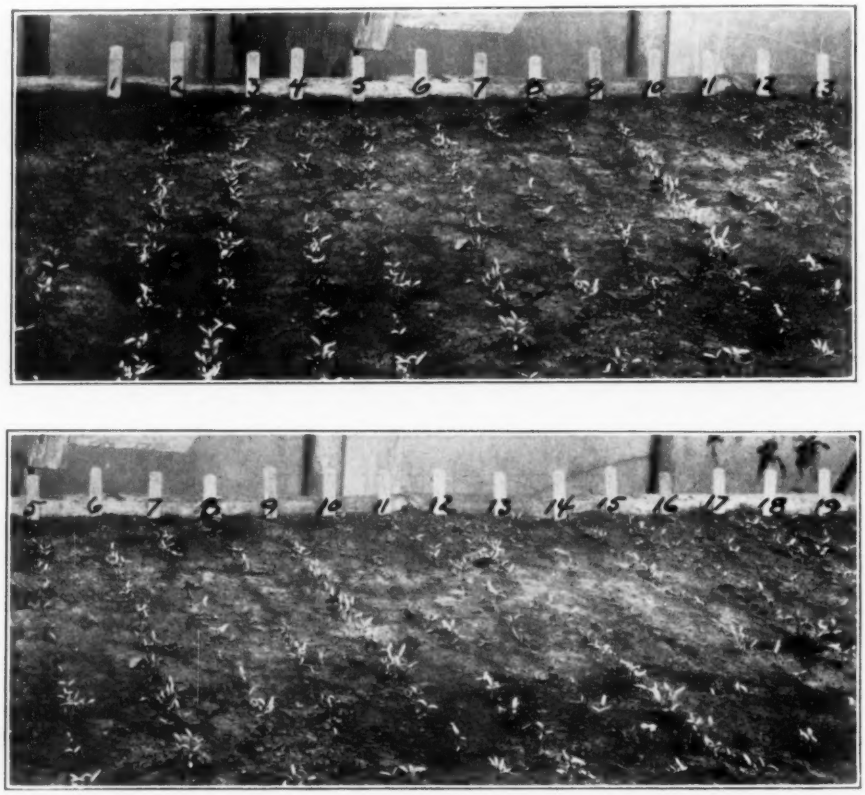

FIG. 1. Experiment 1. A comparison of various sugar beet seed treatments. Rows 1, 4, 7, 10, 13, and 16 were planted with untreated seed. The other rows were planted with seed treated as follows: 2, copper sulphate and lime, dust; 3, copper carbonate, 50 per cent, dust; 5, Seed-O-San; 6, mercury bichloride, 1–1000; 8, formaldehyde 1–240; 9, Chlorophol; 11, Kalimat; 12, Pythal; 14, nickel carbonate.

copper compounds in the form of a dust showed definite promise as a means of control of seedling disease (Fig. 2).

Formaldehyde, Kalimat, and Seed-o-san proved of no value in preventing seedling diseases after the plants have emerged from the soil. Nickel carbonate showed an injurious effect.

EXPERIMENT II

The method of planting was changed for Experiment II and 30 seed balls were used instead of 50. Beginning with this experiment each diseased seedling as removed was plated on cornmeal agar to permit determination of the organism responsible for the disease. The same soil which had previously been employed in Experiment I was used again. The general plan and the results of the test are given in table 2 and illustrated in figure 3.

In this test, the checks again show consistent behavior. Small and large seed balls, various copper compounds, and two concentrations of furfural were compared with the check.

It was thought possible that one of the effects of *Phoma* was the production of small seed balls because of a hypoplastic action upon the mother

FIG. 2. Close view of rows 3 and 4 of Fig. 1, showing seedlings treated with copper carbonate dust contrasted with untreated seedlings. (Cf. table 1.)

plant. Experiment therefore was undertaken to determine the effect of discarding the moderately small seed balls. Preliminary experiments showed that *Phoma betae* occurred on the larger as well as smaller seed balls, and the results obtained in this experiment indicate that disease was still an important factor in reducing stand, and that the apparent gain by the use of large seed balls was simply due to the fact that there were a great many more germs in the case of the large seed balls than in the smaller ones.

The best treatment was the new mercury compound, Semesan, used as a dust in excess. It was best from a point of view of the reduction of disease and best also in stand. Copper compounds ranked about as before, but the faults of the coarse 50 per cent dust were magnified. Neither of the concentrations of furfural tried proved of any value and this compound was eliminated from future tests. Lime, which in some previous tests seemed to have slight promise, proved of no value when used with both the large and the small seed balls.

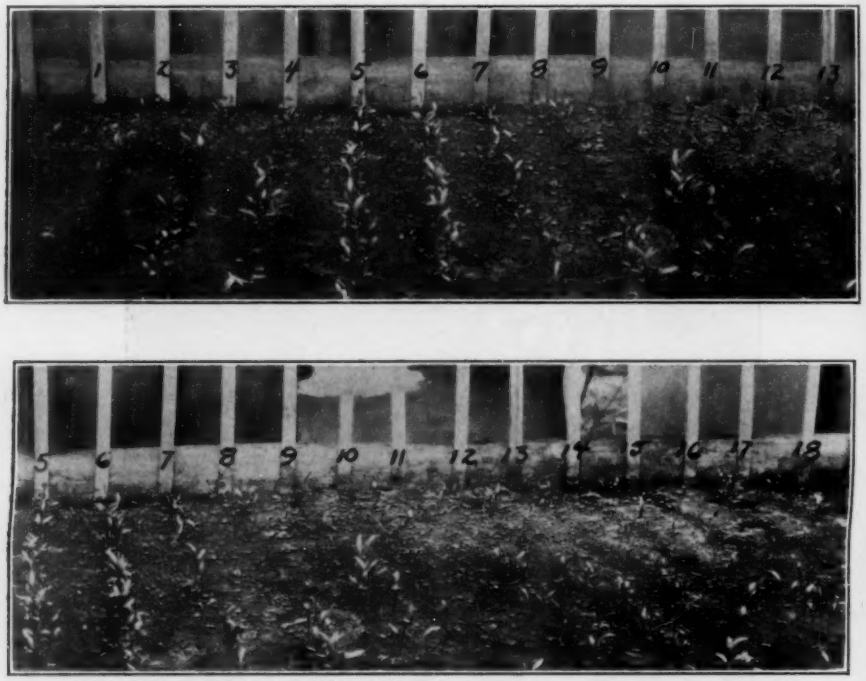

FIG. 3. Experiment II. Repetition of Experiment I with the same muck soil. Rows 1, 4, 7, 10, 13, and 16 were planted with untreated seed. The other rows were planted with seed treated as follows: 2, small seed balls dusted with lime; 3, large seed balls dusted with lime; 5, Semesan, dust; 6, copper carbonate, 18 per cent, dust; 8, copper carbonate, 50 per cent, dust; 9, copper sulphate and lime, dust; 11, furfural, 1 per cent; 12, furfural, 3 per cent. (Cf. table 2.)

The cultures made from the diseased seedlings gave very many Pythium spp. outgrowths. The other fungi and the bacterial growths did not appear consistently and were probably secondary. Not a single culture of *Phoma* or *Rhizoctonia* developed. It is possible that the preliminary disinfection with mercury bichloride influenced the flora which developed.

EXPERIMENT III

The experiments previously reported had been carried on with muck soil. To determine if the type of soil was responsible for the common occurrence of *Pythium*, as well as to take into consideration the various types of soil, sandy loam was substituted for the muck soil. This soil was obtained from a field on the College Farm where beans had been grown the previous summer. There is no record of sugar beets ever having been grown upon this soil. In this experiment various new mercury compounds were used in comparison with some of the chemicals found to be the more or less promising in the previous tests. The plan of the experiment is shown in table 3 and illustrated in figure 4.

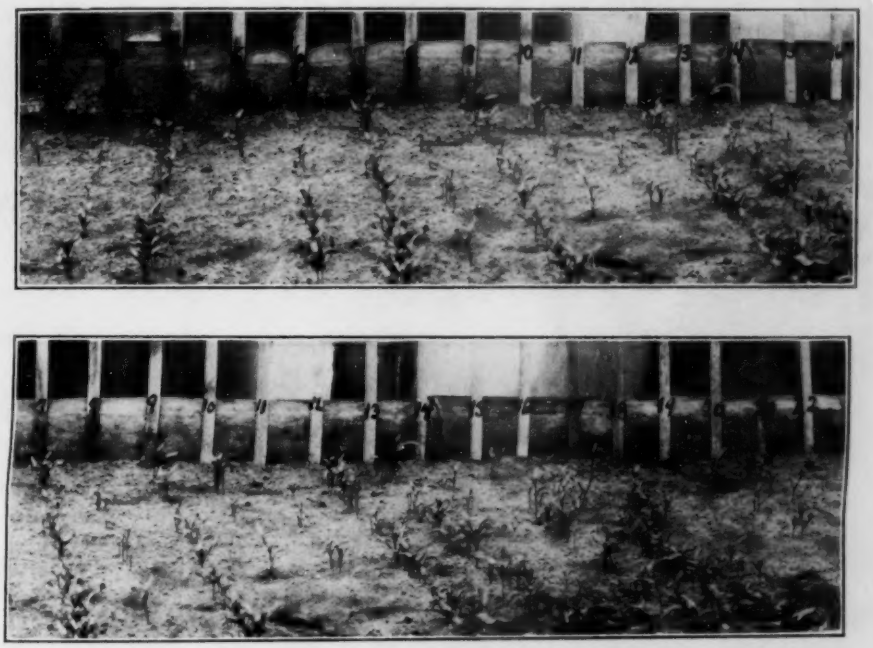

FIG. 4. Experiment III. Sugar beet seed treated in various ways and planted in sandy loam soil. Rows 1, 2, 5, 8, 11, 14, and 17 were planted with untreated seed. The other rows were planted with seed treated as follows: 3, large seed balls, untreated; 4, Pythal; 6, copper sulphate and lime, dust; 7, mercury bichloride, 1–1000; 9, copper carbonate, 18 per cent, dust; 10, formaldehyde, 1–240; 12, Uspulun; 13, Semesan, dust; 15, Chlorophol; 16, Dupont Semesan 13, dust. (Cf. table 3, series B.)

TABLE 3.—*Summary of tests of various sugar beet seed treatments on sandy loam soil; 30 seed balls planted per row. Planting in duplicate. Record taken over a period of 13 days after germination began*

No.	Treatment	Number of seeds germinating		Number of seedlings diseased[f]		Per cent diseased		Per cent of "ideal stand"		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
I	Check	23	20	11	8	48	40	20	20	44	20		
II	Copper sulphate and lime, dust	19	26	0	8	0	31	31	30	15	30	4	
III	Mercury bichloride, 1–1000, 1 hr. soaking	39	53	6	4	15	7.5	55	81	11	68	2	5
IV	Check	16	12	4	4	25	33	20	13	29	16		
V	Copper carbonate, 18 per cent, dust	44	62	5	14	11	23	65	80	17	72	5	3
VI	Formaldehyde, 1–240; 1 hr. soaking	25	23	6	11	24	48	31	20	36	25		
VII	Check	35	13	10	5	28.5	38	41	13	33	27		
VIII	Uspulun,[a] 0.25 per cent; 2 hr. soaking	63	64	10	14	16	22	88	86	19	87	8	2
IX	Semesan, dust	72	62	15	9	21	14.5	95	88	18	91	6	1
X	Check	23	23	5	12	22	52	30	19	37	25		
XI	Chlorophol; 0.25 per cent; 1 hr. soaking	35	43	8	0	23	0	45	71	11	58	3	7
XII	Dupont Semesan 13[b], dust	41	49	7	2	17	4	57	79	10	68	1	4
XIII	Check	21	36	3	15	14	42	30	35	28	32		
XIV	Hulled seeds[c]	0	0										
XV	Pasteurized 60° C.; 10 min.[d]	27	18	13	5	48	28	23	21	38	22		
XVI	Check	22	42	2	13	9	25	33	48	17	40		
XVII	Dry heat, 93° C.; 10 min.	18	26	7	15	39	57	18	18	48	18		
XVIII	Pasteurized 60° C.; 2 consecutive days; 10 min. each[d]	15	17	7	12	47	70	13	8	58	10		
XIX	Check	25	24	6	4	24	17	31	33	20	32		
XX	Dry heat, 110° C.; 10 min.	22	28	2	14	9	50	33	23	29	28		

		22	28	2	14	9	50	33	23	29	28		

TABLE 3.—*Continued*

No.	Treatment	Number of seeds germinating		Number of seedlings diseased		Per cent diseased		Per cent of "ideal stand"		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
XXI	Tillantin B,[e] 0.25 per cent, 1 hr. soaking	13	31	8	17	61	55	8	23	58	15		
XXII	Check	9	24	0	6	0	25	15	30	12.5	22		
XXIII	Tillantin C, 0.25 per cent; 1 hr. soaking	41	42	4	12	10	28	65	50	19	57		8
XXIV	Small seed balls	6	9	3	6	50	67	5	5	58	5		
XXV	Check	21	30	12	15	57	50	15	25	53	20		
XXVI	Large seed balls	21	54	9	33	42	61	20	40	51	30		
XXVII	Pythal, 0.25 per cent, 1 hr. soaking	39	51	3	16	8	31	60	61	19	60	7	6
XXVIII	Check	11	30	9	9	82	30	3	35	56	19		
XXIX	Check	30		13		43		29		43	29		
	Average of checks	23.3 ± 1.25		7.9 ± 0.64									

[a] Uspulun was furnished through the courtesy of the Bayer Company, New York City, and is a mercury compound containing mercury-chlorophenol. It is recommended for use as a 0.25 per cent solution.

[b] Dupont Semesan 13 is an organic mercury compound containing approximately 10 per cent of hydroxymercurichlorophenol, according to analysis furnished by the manufacturer.

[c] Seed balls were crushed and apparently sound seeds selected in an attempt to secure viable material free from the contaminated plant parts.

[d] Seed balls were placed in water at 60° C. in a water bath. After 10 minutes exposure the seeds were divided on blotting paper at 30° C.

[e] Tillantin B and Tillantin C were furnished by H. A. Metz and Co., New York City. The former is a copper compound containing arsenic, and the latter an organic mercury compound.

[f] Diseased seedlings were planted directly upon cornmeal-agar plates without preliminary disinfection, since it was believed that the mercury bichloride affected the flora developing. The following organisms were isolated from diseased seedlings in the groups indicated by Roman numerals (the number in parenthesis denotes the number of times the organism was isolated: I, IV, VII, X, XIII, XVI, XIX, XXII, XXV, XXVIII, XXIX, (the check rows), *Pythium* (7), *Rhizoctonia* (5), *Phoma* (1); II, none; III, *Pythium* (1); V, *Pythium* (1), *Phoma* (1), *Fusarium* (1); VI, *Mucor* (1), *Fusarium* (1), *Pythium* (1); VIII, *Mucor* (1), *Phoma* (1), *Pythium* (3); IX, *Mucor* (2); *Pythium* (1), *Rhizoctonia* (1), *Fusarium* (1); XI, *Pythium* (5), *Fusarium* (1), *Mucor* (1); XII, *Rhizoctonia* (1), *Pythium* (2), *Mucor* (2); XV, *Pythium*. (1); XVII, *Pythium* (1); XVIII, *Mucor* (1), *Alternaria* (1); XX, *Pythium* (2); XXI, *Pythium* (3); XXIII, *Pythium* (1); XXIV, *Pythium* (1), *Mucor* (1); XXVI, *Mucor* (1), *Pythium* (2); XXVII, *Pythium* (1), *Mucor* (2), *Fusarium* (1).

The average total germination of the check rows was 23.3 ± 1.25. The average total diseased seedlings in the checks was 7.9 ± 0.64. These figures are very consistent considering the condition of the test.

It is evident that again the mercury compounds showed the highest total germination and the lowest percentage of disease. The DuPont Semesan 13 showed the fewest diseased seedlings. Chlorophol and mercury bichloride, used as soaking treatments, had approximately the same number of diseased seedlings. On the basis of final stand calculated as percentage of assumed normal stand, Semesan and Uspulun—the former as a dust and the latter as a soaking treatment—rank first and second, respectively. Copper carbonate ranks third, with other compounds following rather closely. The copper sulphate lime dust was not strikingly better than the check in final stand. Tillantin B., a copper compound containing arsenic, was of no value. Soaking the seed balls in formaldehyde 1–240 was of no value.

Pasteurization at 60° C. for ten minutes on one day, and pasteurization on two successive days gave no indication of controlling seedling diseases. While it is possible that the treatment reduced the *Phoma betae* infestation to a great extent, the seedlings were not protected against soil organisms. Dry heat at 93° C. or 110° C. for ten minutes proved of no value as a means of preventing disease.

The separation of the seed balls into two types, small and large, proved to be of no value, confirming the previous test. Attempts to hull the seed were a complete failure. None of the seeds germinated, probably due to injury done in hulling.

In general it may be said that every chemical controlling disease and giving a stand better than the check stand was either a mercury or copper compound.

All seedlings which became diseased in the last six days of the test were plated. Considering that the duplicate rows were one-half the distance of the bed from its corresponding treatment, it will be seen from table 3 that the fungi affecting the seedlings were uniformly distributed throughout the soil; especially was this true of *Pythium*. Seven cultures of *Rhizoctonia* were obtained, five of these occurring in the untreated rows. Three cultures of *Phoma* were found, one from an untreated row. Mucors, Fusaria, and Alternaria were found, but these are looked upon as saprophytes playing but a slight rôle in the seedling disease problem.

EXPERIMENT IV

In order to repeat Experiment III and to demonstrate in miniature the effect of continuous cropping of beets, the soil was used again for planting. The seedlings were removed and the soil thoroughly mixed. It was then

planted to beets. The plan of the experiment is shown in table 4 and illustrated in figure 5. The results are summarized from 17 days' record.

A comparison of the check rows of Experiments III and IV is interesting. The most striking thing about the results is the marked reduction in stand and the increase of disease in the check plats of Experiment IV as compared with the previous experiment. Conditions within the greenhouse, and water relations of the bed were not noticeably different in the two experiments, and we feel secure in attributing the differences in stand to the intensification of pathogens which came from the preceding crop.

The 21 untreated rows in Experiment IV showed a total germination of 8 $\pm$ 0.51 seedlings as contrasted with 23.3 $\pm$ 1.25 in Experiment III.

Assuming an average of 2 germs per seed ball, these figures show that the total number of seedlings emerging was only 13 per cent of the normal as contrasted with 38 per cent in the former test. In Experiment IV, 61

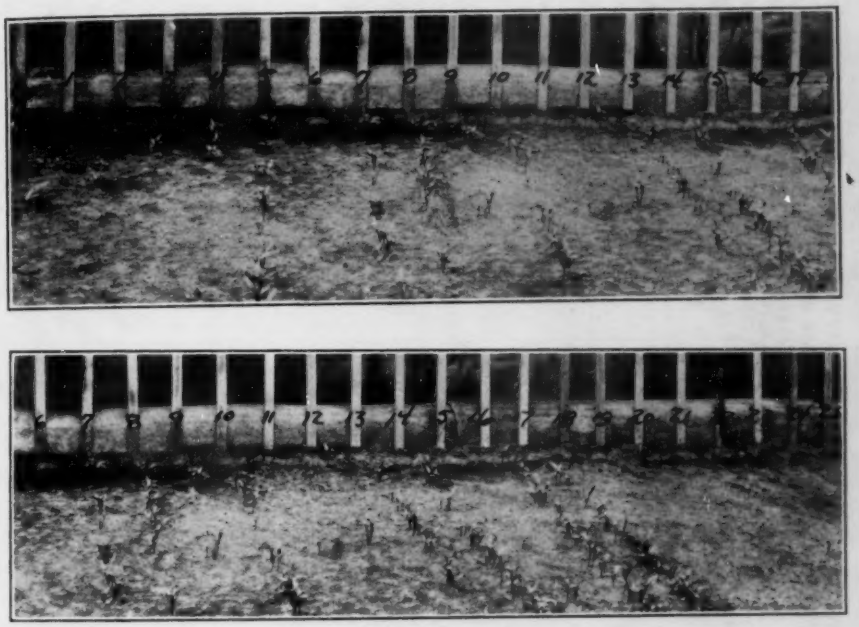

FIG. 5. Experiment IV, a. Repetition of seed treatment Experiment III using the sandy loam soil a second time for seedlings. Rows 3, 6, 9, 12, 15, 18, 21, and 24 were planted with untreated seed. The other rows were planted with seed treated as follows: 1, Tillantin C; 2, small seed balls, untreated; 4, large seed balls, untreated; 5, Pythal; 7, copper sulphate and lime, dust; 8, mercury bichloride, 1–1000; 10, copper carbonate, 18 per cent, dust; 11, formaldehyde, 1–240; 13, Uspulun; 14, Semesan, dust; 16, Chlorophol; 17, Dupont Semesan 13, dust; 19, hulled seed; 20, pasteurized seed balls; 22, dry heat, 93° C. (Cf. table 4, series B.)

TABLE 4.—*Repetition of sugar beet seed treatments outlined in table 3; same sandy loam soil used after thorough mixing. Record taken over a period of 17 days after germination began*

No.	Treatment	Number of seeds germinating		Number of seedlings diseased[a]		Per cent diseased		Per cent of "ideal stand"		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
I	Check	5	10	1	7	20	70	6	11	45	8		
II	Copper sulphate and lime, 50–50, dust, in excess	16	54	1	33	6	61	25	35	33	30	8	8
III	Mercury bichloride, 1–1000, 1 hr. soaking	43	37	14	11	32	30	48	43	31	45	5	4
IV	Check	5	12	2	6	40	50	5	10	45	7		
V	Copper carbonate, (18 per cent) dust in excess	38	31	9	13	23	41	48	30	32	39	7	6
VI	Formaldehyde, 1–240; 1 hr. soaking	9	2	3	1	33	50	10	1	41	5		
VII	Check	5	12	1	7	20	58	6	8	39	7		
VIII	Uspulun 0.25 per cent; 2 hr. soaking	32	39	11	7	34	18	35	53	31	44	4	5
IX	Semesan; dust in excess	49	47	12	11	24	23	61	60	23	60	3	2
X	Check	5	8	1	5	20	62	6	5	41	5		
XI	Chlorophol, 10 gm. per gal., 1 hr. soaking	35	50	2	6	5	12	55	73	8	64	1	1
XII	Dupont Semesan, No. 13; dust in excess	48	53	13	20	27	38	58	55	32	56	6	3
XIII	Check	8	3	2	3	25	100	10	0	62	5		
XIV	Hulled seeds	0	0										
XV	Pasteurized 60° C.; 10 min.	5	8	5	7	100	87	0	0	93	0		
XVI	Check	12	6	3	3	25	50	5	1	37	3		
XVII	Dry heat, 93° C.; 10 min.	18	12	14	11	78	92	6	1	85	3		
XVIII	Pasteurized 60° C.; 10 min. on 2 consecutive days	9	5	8	4	89	80	1	1	84	1		

TABLE 4.—*Continued*

	tive days	9	5	8	4	89	80	1	1	84	1		

TABLE 4.—*Continued*

No.	Treatment	Number of seeds germinating		Number of seedlings diseased[a]		Per cent diseased		Per cent of "ideal stand"		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
XIX	Check	10	5	6	5	60	100	6	0	80	3		
XX	Dry heat, 110° C.; 10 min.	4	7	3	4	75	57	1	5	66	3		
XXI	Tillantin B, 0.25 per cent, 1 hr. soaking	22	10	12	7	55	70	16	5	62	10		
XXII	Check	8	9	3	5	38	56	8	6	47	7		
XXIII	Tilantin C, 0.25 per cent, 1 hr. soaking	20	36	13	10	65	28	11	43	46	27		
XXIV	Small seed balls	3	3	0	1	0	33	5	3	16	4		
XXV	Check	6	13	3	3	50	23	5	5	36	5		
XXVI	Large seed balls	22	18	10	12	45	67	20	10	56	15		
XXVII	Pythol, 1 per cent, 1 hr. soaking	36	21	3	5	8	23	55	26	15	35	2	7
XXVIII	Check	4	10	4	9	100	90	0	1	95	0		
XXIX	Check		9		8		89		1	89	1		
	Average of checks	8 ± 0.51		4.9 ± 0.43									

[a] The following organisms were isolated from diseased seedlings in the groups indicated by Roman numeral (the number in parenthesis denotes the number of times the organism was isolated): I, IV, VII, X, XIII, XVI, XIX, XXII, XXV, XXVIII, XXIX (the check rows), *Pythium* (25), *Rhizoctonia* (8), *Phoma* (1), *Mucor* (18), *Fusarium* (18), miscellaneous (7). II, Series A, *Pythium* (1); Series B, *Pythium* (6), *Mucor* (6), *Phoma* (1), *Fusarium* (1), *Rhizoctonia* (11). III, Series A, *Pythium* (2), *Fusarium* (4), *Mucor* (3), *Penicillium* (1); Series B, *Phoma* (1), *Fusarium* (3), *Pythium* (3), *Mucor* (3). V, Series A, *Fusarium* (6), *Pythium* (3); Series B, *Fusarium* (3), *Mucor* (3), *Pythium* (7). VI, Series A, *Pythium* (1), *Mucor* (1), *Fusarium* (1); Series B, none. VIII, Series A, *Pythium* (5), *Mucor* (1), *Fusarium* (3); Series B, *Rhizoctonia* (1), *Mucor* (2). IX, Series A, *Pythium* (3), *Fusarium* (4); Series B, *Phoma* (4), *Fusarium* (4), *Pythium* (1). XI, Series A, *Fusarium* (1), *Mucor* (1); Series B, *Pythium* (3), *Rhizoctonia* (1), *Sordaria* (1). XII, Series A, *Pythium* (8), *Mucor* (3), *Fusarium* (1); Series B, *Pythium* (6), *Mucor* (1). XV, Series A, *Rhizoctonia* (1), *Fusarium* (3); Series B, *Pythium* (2), *Fusarium* (2). XVII, Series A, *Phoma* (1), *Fusarium* (4), *Mucor* (3), *Pythium* (4); Series B, *Pythium* (2), *Fusarium* (4), *Phoma* (1), *Mucor* (2). XVIII, Series A, *Pythium* (3), *Mucor* (3), *Fusarium* (2); Series B, *Fusarium* (3), *Pythium* (1). XX, Series A, *Pythium* (1), *Alternaria* (1); Series B, *Pythium* (2), *Mucor* (1). XXI, Series A, *Pythium* (4), *Mucor* (4), *Fusarium* (2); Series B, *Pythium* (1), *Alternaria* (1), *Fusarium* (1). XXIII, Series A, *Fusarium* (6), *Mucor* (2), *Pythium* (2); Series B, *Fusarium* (6), *Pythium* (2), *Mucor* (3). XXIV, Series B, *Mucor* (1). XXVI, Series A, *Pythium* (4), *Fusarium* (4), *Mucor* (2); Series B, *Pythium* (2), *Fusarium* (4), *Rhizoctonia* (1), *Mucor* (1). XXVII, Series A, *Pythium* (2); Series B, *Pythium* (1), *Fusarium* (2).

per cent of the seedlings emerging became diseased, and the final stand on the average was only 5 per cent of the assumed normal stand. In Experiment III approximately 33 per cent of the seedlings which emerged became diseased and the final stand was 25 per cent of the assumed normal stand.

These figures illustrate in forcible manner the influence a diseased crop may have upon a succeeding crop. With such soil infestation, it is obvious that the various seed treatments are put to extreme tests as to their capacity for protecting the young seedling as it emerges and grows into the soil.

With every treatment the stand in Experiment IV is poorer than in Experiment III and the percentage of disease is higher. The results with the various seed treatments are gratifying, however, considering the soil infestation. The superior treatments of Experiment III stand high also in Experiment IV. Based upon percentage of assumed normal stand, the treatments have the following position: Chlorophol, Semesan dust, Du Pont Semesan 13, mercury bichloride (1–1000), and Uspulun (0–25 per cent). The copper compounds and Pythol gave from 30 to 40 per cent of the possible stand with a disease percentage ranging from 15 in the case of Pythal to 33 in the case of copper sulphate-lime dust. The other treatments gave no indications of control, thus confirming previous tests.

A large number of Pythium cultures were obtained from the diseased seedlings. In fact, *Pythium* appeared as frequently as with the muck soil used in Experiment II. In a few instances *Phoma* and *Rhizoctonia* were found; *Rhizoctonia* was more common on the untreated rows. A large number of growths of *Fusarium* and *Mucor* developed.

EXPERIMENT V

In order to compare the influence of the seed-borne organisms with those arising from the soil in their effects upon stand and upon the prevalence of disease, an experiment was planned in which the sandy loam soil previously used was left in one half of the greenhouse bed and the other half of the bed, after disinfection with strong formaldehyde, was filled with clean sand. The most satisfactory treatments of the preceding tests were chosen, and pasteurization at 60° C. for 10 minutes on two successive days was also included because of the reports that have been given as to its value in eliminating *Phoma betae*. The plan of the experiment with sandy loam soil along with the summary of the record at the close of a 14-day period is given in table 5 and illustrated in figure 6. Table 6 and figure 7 give similar data for the portion of the bed containing clean sand.

The results of this experiment can probably best be made clear by contrasting the behavior of the untreated seed in soil and sand. The total

germination of the checks in sand was 35.0 ± 0.81 and of these 11.4 ± 1.00 were diseased. On the other hand, the untreated seed in the soil series showed a total germination of only 10.1 ± 0.67 seedlings of which 5.1 ± 0.40 were diseased. These figures show in a striking way the rôle that soil organisms play in the production of seedling diseases.

FIG. 6. Experiment V. Sandy loam soil series of seed treatments. Rows 1, 2, 5, 8, 11, 14, and 17 were planted with untreated seed. The other rows were planted with seed treated as follows: 3, copper sulphate and lime, dust; 4, mercury bichloride, 1–1000; 6, copper carbonate, 18 per cent, dust; 7, pasteurized; 9, Chlorophol; 10, Semesan, dust; 12, Uspulun; 13, Dupont Semesan 13; 15, copper sulphate and lime, dust. (Cf. table 5, series A.)

FIG. 7. Experiment V. Clean sand series of seed treatments. The rows in this test duplicate those given in the legend of figure 6. (Cf. table 6, series A.)

TABLE 5.—*Summary of sugar beet seed treatments on sandy loam soil: third planting on same soil. Period, 14 days after germination*

No.	Treatment	Number of seeds germinating		Number of seedlings diseased[a]		Per cent diseased		Per cent of "ideal" stand		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
I	Check	14	11	6	8	43	73	13	5	58	9		
II	Copper sulphate-lime; dust in excess	18	22	6	10	33	45	20	20	39	20	6	7
III	Mercury bichloride, 1–1,000; 1 hr. soaking	15	22	10	6	66	23	25	26	44	25	7	6
IV	Check	15	9	6	3	60	33	15	10	46	12		
V	Copper carbonate, 18 per cent; dust in excess	19	34	4	13	21	38	25	35	29	30	4	5
VI	Pasteurized; 60° C., 20 min.	9	13	5	5	55	38	6	13	46	9		
VII	Check	12	15	7	6	58	60	8	15	59	12		
VIII	Chlorophol, 0.25 per cent; 1 hr. soaking	40	49	7	4	17	8	55	75	12	65	1	2
IX	Semesan; dust in excess	50	50	12	15	24	30	63	58	27	60	3	3
X	Check	8	8	2	6	25	75	10	3	50	6		
XI	Uspulun, 0.25 per cent; 2 hrs. soaking	44	38	12	17	27	45	53	35	36	44	5	4
XII	Dupont Semesan, No. 13; dust in excess	47	46	4	9	9	19	71	61	14	66	2	1
XIII	Check	8	5	4	3	50	60	6	3	55	4		
XIV	Check		7		6	85				85			
	Average of checks	10.1 ± .67		5.1 ± .4									

[a] The following organisms were isolated from diseased seedlings in the groups indicated by Roman numeral (the number in parenthesis denotes the number of times the organism was isolated): I, IV, VII, X, XIII, XIV (the check rows), *Pythium* (29), *Fusarium* (9), Bacteria (2). II, Series A, *Pythium* (5), *Fusarium* (1); Series B, *Pythium* (3), *Phoma* (1), *Fusarium* (1). III, Series A, *Fusarium* (2), *Pythium* (6); Series B, *Pythium* (2), *Fusarium* (2). V, Series A, *Fusarium* (1), *Pythium* (2); Series B, *Pythium* (11). VI, Series A, *Phoma* (1), *Pythium* (4); Series B, *Pythium* (2), *Fusarium* (3). VIII, Series A, *Pythium* (2), Bacteria (2); Series B, *Pythium* (2). IX, Series A, *Pythium* (5), *Fusarium* (2); Series B, *Pythium* (9), *Fusarium* (2). XI, Series A, *Pythium* (8); Series B, *Pythium* (4), *Rhizoctonia* (2), *Fusarium* (3). XII, Series A, *Pythium* (2), *Fusarium* (2); Series B, *Pythium* (6), Fusarium (3).

TABLE 6.—*Summary of sugar beet seed treatments on clean sand: for comparison with tests given in table 5. Period, 14 days after germination*

No.	Treatment	Number of seeds germinating		Number of seedlings diseased[a]		Per cent diseased		Per cent of "ideal" stand		Averages		Rank based upon	
		Series A	Series B	Series A	Series B	Series A	Series B	Series A	Series B	Per cent diseased	Per cent of stand	Freedom from disease	Stand
I	Check	35	31	11	21	31	68	40	16	49	28		
II	Copper sulphate-lime; dust in excess	39	40	12	10	31	25	45	50	28	57		8
III	Mercury bichloride, 1–1,000; 1 hr. soaking	39	62	7	6	18	10	55	91	14	73	6	5
IV	Check	31	37	14	5	45	13	28	53	29	40		
V	Copper carbonate, 18 per cent; dust in excess	43	47	6	8	14	18	61	65	16	63	7	7
VI	Pasteurized; 60° C., 20 min.	53	55	3	1	5	2	83	90	3	86	4	2
VII	Check	37	33	13	12	35	36	40	35	35	37		
VIII	Chlorophol, 0.25 per cent; 1 hr. soaking	39	43	0	1	0	2	65	70	1	67	1	6
IX	Semesan; dust in excess	58	82	1	4	2	5	95	130	3	112	3	1
X	Check	43	28	9	12	21	42	56	26	31	41		
XI	Uspulun, 0.25 per cent; 2 hrs. soaking	51	55	2	6	4	11	81	81	7	81	5	3
XII	Dupont Semesan, No. 13; dust in excess	51	47	0	3	0	6	85	73	3	79	2	4
XIII	Check	38	38	3	10	8	26	58	46	17	52		
XIV	Check		36		16		44		33	44	33		
	Average of checks	35.0 ± .81		11.4 ± 1.00									

[a] The following organisms were isolated from diseased seedlings in the groups indicated by Roman numeral (the number in parenthesis denotes the number of times the organism was isolated: I, IV, VII, X, XIII, XIV (the check rows), *Phoma* (106), *Pythium* (3), *Alternaria* (2), Bacteria (4). II, Series A, *Phoma* (12); Series B, *Phoma* (10). III, Series A, *Phoma* (5); Series B, *Phoma* (6). V, Series A, *Phoma* (3); Series B, *Phoma* (6). VI, Series A, *Phoma* (3); Series B, *Phoma* (1). VIII, Series B, Bacteria (1). IX, Series A, *Phoma* (1); Series B, *Phoma* (2). XI, Series A, *Phoma* (1); Series B, *Phoma* (4). XII, Series B, *Phoma* (2).

In the soil series in spite of the heavy infestation with pathogens, the mercury compounds still showed considerable control and the figures obtained are approximately the same as those obtained in Experiment IV. The copper sulphate-lime dust was not so satisfactory as in former tests. Copper carbonate was superior to the soaking treatment with mercury bichloride. The pasteurized seed was but slightly better than the untreated seed.

When the data from the soil and sand experiments are compared, some outstanding things are shown. First, seedlings receiving the pasteurization treatment which had proved to be of no value in the soil tests now ranked second in stand and fourth in freedom from disease in the sand planting. Semesan was the outstanding chemical in this test, giving a stand better than the assumed normal. In disease reduction Chlorophol ranks first, with Du Pont Semesan 13, Semesan, and pasteurization treatments showing approximately the same number of diseased seedlings and the same percentage diseased of the total number germinating. Copper carbonate again compares favorably with mercury bichloride soaking treatment.

The results from the untreated rows on sand give some idea as to the real importance of *Phoma betae*. Thirty-three per cent of the seedlings appearing above the surface of the sand became diseased and with few exceptions *Phoma* was responsible. Three cultures of *Pythium* were found but they came from the buffer row nearest the row of bricks which separated the sand from the soil portion of the bed. Based upon the assumed normal number that should have appeared if *Phoma* had been eliminated, 44 per cent of the seedlings were killed below the surface of the ground and 11.4 of those emerging contracted Phoma disease. It is doubtless true that *Phoma* was actively concerned in the death of seedlings in the previous experiments but the rapidity of growth of other organisms and the mixed infections masked the situation.

The writers assume that the *Phoma* in this experiment came from the seed ball. No examination of the sand used in this experiment was made, but it seems that it may be safely eliminated as a source of the fungus, since the sand was fresh from the sand pit and had no chance of being contaminated with beet débris.

This test shows that beet balls can not be completely freed from *Phoma betae* by any one of the treatments tried with the possible exception of Chlorophol. This chemical has not given a very good stand. The results with the mercury compounds, however, are promising because of the marked disease reduction. Copper carbonate also has given fair results.

EXPERIMENT VI

In the experiment just reported, clean sand and infested sandy loam soil were compared in their general effect on stand and percentage of dis-

ease. In order to determine if the physical nature of the substratum played any rôle in the results obtained in the previous planting the following experiment was performed.

The soil and the sand used in Experiment V was autoclaved at 15 pounds pressure for an hour. New greenhouse flats, 16 by 20 by 3 inches, were filled with the sterilized soil and the sterilized sand. Similar flats were prepared with the non-sterile soil and non-sterile sand. Three rows of 30 seed balls each were planted in each of the four flats. The middle row in each case was planted with seed balls which had been dusted with Semesan as a dust (in excess). The record taken 12 days after germination began showed the results given in table 7.

The results of this test are entirely confirmatory of the previous tests and indicate that the important factor in the production of the disease of the seedlings is not the physical character of the soil but rather its fungous content. The results with sterilized soil and sterilized sand are very similar and the non-sterile sand showed approximately the readings of the autoclaved sand. In non-sterile soil the stand was almost a complete failure in the case of the untreated seed, and only 16 seedlings grew in the case of the

TABLE 7.—*Comparison of sugar beet seedling diseases on autoclaved soil and sand and on non-sterile soil and sand: Tests made in flats, 3 rows per flat, 30 seed balls per row. Period 18 days*

	Seed treatment	No. of seedlings emerged	No. of seedlings diseased
Autoclaved sand	Untreated	25	4
	Semesan[a]	56	2
	Untreated	28	2
Autoclaved soil	Untreated	28	5
	Semesan[a]	58	2
	Untreated	33	3
Non-sterile sand	Untreated	27	3
	Semesan[a]	66	1
	Untreated	40	2
Non-sterile soil	Untreated	2	0
	Semesan[a]	16	1
	Untreated	1	0

[a] Semesan used as a dust in excess.

Semesan treatment. This was the fourth crop of seedlings for this soil, and a comparison of the results with those of the preceding experiments shows the progressive increase in disease organism contamination. Here again the

Semesan treatment was put to an extremely severe test: the stand resulting was only 27 per cent of the assumed normal, a gain, however, of approximately 24 per cent over the checks. A study of the results with treated and untreated seed obtained with sand, both sterile and unsterile, and with the autoclaved soil shows that the organisms carried on the seed play an exceedingly important rôle in influencing stand, the germination of the treated seed being approximately double that of the untreated seed.

EXPERIMENT VII

To compare the pathogenicity of the three principal organisms concerned with damping-off of the beet seedlings, inoculation experiments were performed with organisms from the following sources:

1. *Phoma betae* isolated from a diseased seedling growing in sterile sand.
2. *Phoma betae* from diseased sugar beet seed from Colorado.
3. *Rhizoctonia* spp. from a diseased seedling.
4. *Rhizoctonia* spp. from laboratory stock culture isolated from potato.
5. *Pythium debaryanum* isolated from a diseased seedling growing in soil.

About three weeks before the seed balls were planted the organisms named above were planted on sterilized cornmeal in liter flasks. Clean building sand was sterilized, and the greenhouse flats were disinfected by soaking in formaldehyde 1–10. The cornmeal, which in three weeks became covered and impregnated with the fungous growth, was thoroughly mixed with the sterile sand. Two rows of untreated seed and one row of seed dusted with Semesan were planted in each flat, 30 seed balls per row. The results of the experiment are given in table 8 and illustrated in figure 8.

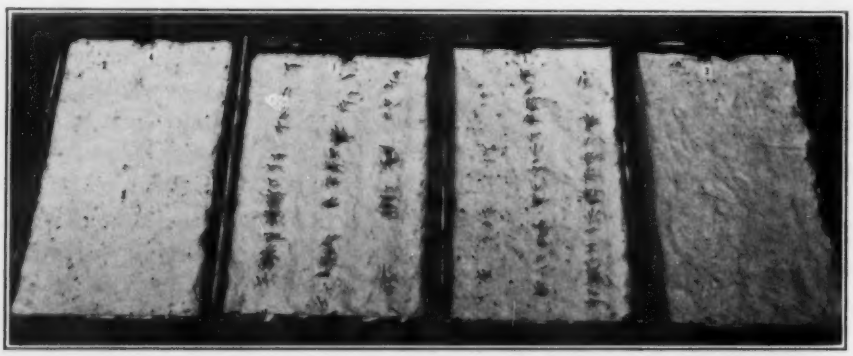

FIG. 8. Flats of sterilized sand to which cultures of various organisms were added three weeks before the seed balls were planted compared with a flat of sterile sand. Photographed three weeks after the seed was planted.

Flat 1: Check. 2: *Rhizoctonia* from a beet seedling. 3: *Pythium* spp. from a beet seedling. 4: *Phoma betae*.

TABLE 8.—*Inoculation experiments with three sugar beet disease organisms. Sterile sand in flats inoculated by adding 3 weeks old cultures of the organisms on cornmeal*

TABLE 8.—*Inoculation experiments with three sugar beet disease organisms. Sterile sand in flats inoculated by adding 2-weeks-old cultures of the organism on cornmeal*

Flat no.	Organism used to inoculate flats	Treatment given seed balls	No. of seedlings emerging	No. of seedlings diseased	Organisms isolated from diseased seedlings
1	*Phoma betae* obtained from beet seedling	Untreated	1	1	*Phoma* (1)
		Semesan[a]	1	1	*Phoma* (1)
		Untreated	0	–	
2	*Phoma betae* isolated from a sugar-beet grown in Colorado	Untreated	0	–	
		Semesan	7	7	*Phoma* (6)
		Untreated	2	2	*Mucor* (1)
3	*Pythium debaryanum* obtained from a seedling	Untreated	0	–	
		Semesan	0	–	
		Untreated	0	–	
4	*Corticium vagum solani* ("Rhizoctonia") from seedling	Untreated	16	2	*Rhizoctonia* (2)
		Semesan	52	15	*Rhizoctonia* (13), no growth (1), *Alternaia* (1)
		Untreated	39	9	*Rhizoctonia* (9)
5	*Corticium vagum solani* from potato. ("Rhizoctonia")	Untreated	25	7	*Rhizoctonia* (4), *Mucor* (2)
		Semesan	39	11	*Rhizoctonia* (5), *Mucor* (2)
		Untreated	34	12	*Rhizoctonia* (4), *Mucor* (2)
6	Mixture of cornmeal cultures of *Phoma betae*, *Pythium debaryanum*, *Corticium vagum solani* used in flats 1, 3, and 4; light inoculation	Untreated	9	5	*Rhizoctonia* (5), *Pythium* (1)
		Semesan	26	20	*Phoma* (2), *Pythium* (2), *Rhizoctonia* (12)
		Untreated	11	8	*Phoma* (1), *Rhizoctonia* (6)
7	Sterile cornmeal—check	Untreated	30	6	*Mucor* (4), *Alternaria* (1)
		Semesan	34	3	Bacteria (1), *Mucor* (1)
		Untreated	26	10	*Phoma* (2), *Mucor* (5), *Bacteria* (1)
8	Sterile sand—check	Untreated	40	5	*Phoma* (1), Bacteria (3), *Alternaria* (1)
		Semesan	44	0	
		Untreated	44	1	*Mucor* (1)

[a] Semesan dust was used in excess.

In the flat inoculated with *Pythium* no seedlings appeared. Even the row of seed balls treated with Semesan failed completely. Examination showed that the seed had sprouted but the young seedlings were killed by *Pythium* before reaching the surface of the soil. With such heavy inoculation the Semesan was not able to ward off the organism. It is possible that with the sand as a substratum the toxic ingredients of the Semesan were more widely dissipated than they would have been if the finer and more absorptive soil particles were present to bind the heavy metal by adsorption.

Phoma betae was almost as severe in its effects as *Pythium*. A few seedlings came above the surface in each of the two tests with *Phoma*, but these soon became diseased. Under the conditions of this test, Semesan failed to protect the young plants.

The flats inoculated with *Rhizoctonia* gave results at marked variance with those inoculated with *Pythium* and *Phoma*. The inoculum which was applied to the soil soon gave rise to a very heavy growth of the organism. This was very evident even before the seedlings emerged from the sand, for the fungus had grown so strongly as to crust the soil. It will be noted in table 8 that a considerable number of seedlings appeared. The results after the first 12 days seemed to indicate that *Rhizoctonia* was a rather weak or at least a slowly working parasite. Twenty-four days after the germination of the seedlings began, the flats were discarded. Special attention was given to the Rhizoctonia-inoculated flats and each seedling was carefully washed out of the sand and examined. It was found that almost every seedling from the check rows in both flats had a decayed root tip (Figure 9). The Semesan rows were slightly better than the check rows. The strain of *Rhizoctonia* from potato was as effective as the strain isolated from the beet seedling. Where the root tip was decayed the plant had thrown out from 3 to 8 small rootlets just above the decayed region to compensate for the loss of the primary root system. The hypocotyl was sound above the surface of the sand but the leaves were not of normal color. A few showed signs of wilting. It seemed extremely likely that in many cases the seedling would have succeeded in replacing the diseased portion and would have remained alive. The resulting beet root would have been forked and sprangled, and it seems extremely probable that the forked and sprangled roots so common in some fields at harvest time which have been attributed to high water table or impervious subsoil are more properly to be attributed to Rhizoctonia which has been influenced by the above named factors.

The results with the mixture of all of the organisms gave some results of considerable interest. The inoculum for this flat was made by taking a small amount of the sand from flats 1, 3, and 4 and mixing thoroughly.

The amount of inoculum added was small. A greater number of seedlings emerged in the untreated rows in this flat and Semesan had slightly more influence in warding off disease. In the isolations only a few cultures of *Phoma betae* and *Pythium* spp. were obtained, *Rhizoctonia* spp. being by far the most common. This at first glance seems contradictory considering the strong pathogenicity of *Pythium* spp. and *Phoma betae* shown in the other flats. The plausible explanation is that the seedlings attacked by *Pythium* spp. and *Phoma betae* were killed before reaching the surface. The seedlings which survived probably escaped *Pythium* and *Phoma betae* but did harbor the slower working *Rhizoctonia*.

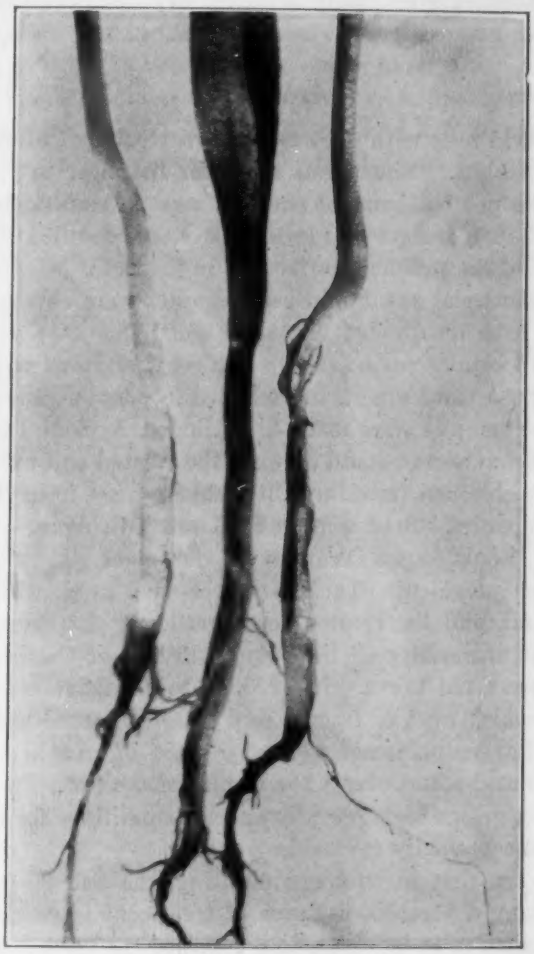

FIG. 9. Typical Rhizoctonia diseased seedlings from Flat 2 of figure 8.

The same explanation is probably applicable in the case of the various isolations made in the preceding experiments. In spite of the high infestation of seeds by *Phoma betae*, only a few cultures were obtained. It seems probable that seedlings affected with *Phoma betae*, in large part, under the greenhouse conditions, did not appear above the surface.

In one flat, cornmeal alone was added to the sand to determine the effect of adding this organic nutrient. The total number of seedlings was reduced below that in the sterile sand and the number of diseased seedlings was increased. It seems plausible to attribute these results to some influence of the cornmeal medium upon the organisms present on the seed balls.

The sterile sand gave results in harmony with the previous test on sand. *Phoma betae* was isolated from a diseased seedling.

FIELD TESTS

Since 1922 field tests with various types of treatment of sugar beet seed have been carried out. These tests have, for the most part, been unsatisfactory from the point of view of showing marked results from treatment. The results, although meager and inconclusive, are detailed since they indicate the nature of the problem confronted in the field.

In 1922, commercial sugar beet seed samples were obtained from three companies and each lot divided into three portions. One part of each lot was dusted with copper carbonate, 18 per cent, and one with copper sulphate-lime dust. A third sample of each seed lot was left untreated. Plantings of the nine samples were made at Michigan Agricultural College and there were no differences in stand between the treated and untreated. Similar reports were obtained from Bay City and Saginaw from the cooperating commercial companies. Seed sent to St. Louis, Michigan, was planted by the Holland-St. Louis Sugar Company in rich black soil in which root rot had always been prevalent. These were reported as showing marked differences in stand, and the treated rows stood out all through the season, both because of uniformity of the stand and size of the beets. Unfortunately, yields were not taken. In 1923, more extensive experiments were carried out in which rows of treated seed were compared with rows of untreated seed. Larger plantings were also made of treated seed. Table 9, giving the estimated stand, shows the results of the test. In both cases the soil used had not grown beets recently and the conditions for germination of the seed were exceptionally favorable.

It will be seen that in only one planting, the Schreiber seed at East Lansing, were any differences in favor of treatment to be noted, and these were not so marked as to influence final stand of the beets. The late planting and the influence of the season evidently prevented seedling diseases playing any especial rôle in reducing stand.

A greenhouse planting of the same seed showed results with both sand and soil entirely consistent with former results in the greenhouse. In this test the average stand of the untreated American-grown seed in infested soil was 24 per cent of the assumed normal, and in clean sand it was 27 per cent. Chlorophol and copper carbonate treatments increased the stand. In sand, the final stand was 27 per cent of the assumed normal, and Chlorophol and copper carbonate nearly doubled the stand. Similar results were obtained with Schreiber seed, but the average stand of the Schreiber seed was slightly lower than the American grown seed.

In a field test at St. Louis, Michigan, on a 16-row plot, 37 rods long, different foreign varieties were compared with treated and untreated American grown seed, and the highest tonnage was obtained from treated American grown seed. The results are given in table 10.

In 1924 further comparisons of the treated and untreated seed were made and 3 fields were planted, half to treated and half to untreated seed. On two of the farms no differences in the treated and untreated portions could

TABLE 9.—*Field tests of sugar beet seed treatments at East Lansing and St. Louis Mich. Single rows planted with hand planter. Planted at East Lansing, June 7, 1923; stand estimated June 15, 1923. Planted at St. Louis June 2, 1923; stand estimated June 22, 1923*

Treatment	Stand of Schreiber seed in per cent		Stand of American grown seed in per cent	
	E. Lansing	St. Louis	E. Lansing	St. Louis
Untreated	80	93	100	94
Copper sulphate-lime dust, 6 oz. per 15 lbs. seed	98	98	80	98
Copper carbonate, 18 per cent, dust, 4 oz. per 15 lbs. seed	100	95	80	96
Untreated	70	96	100	92
Copper carbonate, 18 per cent, dust, 6 oz. per 15 lbs. seed	100	96	80	98
Copper carbonate, 18 per cent, dust, in excess	80	96	95	98
Untreated	60	94	80	95
Sulphur; in excess	30	92	80	95
Formaldehyde, 1–240; 30 minutes soaking	98	94	100	92
Untreated	70	94	100	92
Chlorophol, 0.25 per cent; 1 hour soaking	100	95	100	95
Semesan; dust, 4 oz. per 15 lbs. seed	70	95	90	92
Untreated	100	95	100	92

TABLE 10.—*Field tests of treated and untreated sugar beet seed, with standard varieties for comparison: plots consisting of 16 rows, 37 rods long (approximately 0.4 acre), St. Louis, Michigan,[a] 1923*

Variety and treatment	Yield per plot in pounds	Sugar percentage
Schreiber and Sohn sugar-beet seed	10,640	15.5–15.5
Home-grown seed treated with copper carbonate, 18 per cent, 4 oz. per 15 lb. seed	11,260	14.4–15.1
Home-grown seed untreated	8,465	14.6–15.1
Danish-grown Kleinwanzlebener	10,300	15.2–15.7
American Beet Sugar Co., leaf-spot resistant seed	9,305	14.6–15.4
Delitzcher	9,005	15.0–15.6

[a] Figures through courtesy of Mr. B. C. Hubbard, manager of Holland-St. Louis Sugar Co., St. Louis, Michigan.

TABLE 11.—*Field tests[a] of various sugar beet seed treatments at East Lansing and St. Louis, Michigan, in 1924. Summary of estimates on per cent of stand made before thinning*

Treatment	Stand obtained in per cent	
	East Lansing	St. Louis
Semesan dust	97.5	100
Mercury bichloride, 1–1,000, 1 hr. soaking	95.5	90
Copper carbonate, 50 per cent, dust	94.0	90
Dupont Semesan, No. 13, dust	85.0	95
Uspulun, 0.25 per cent; 1 hr. soaking	85.0	70
Uspulun, 0.25 per cent; 60° C. for 20 minutes	83.0	60
Semesan, 0.25 per cent; 60° C. for 20 minutes	83.0	60
Copper sulphate-lime dust	82.5	70
Copper carbonate, 18 per cent, dust	80.0	85
Mercury bichloride, 1–1,000; 60° C. for 20 minutes	77.0	80
Small seed balls	69.0	80
Large seed balls	62.5	85
Pasteurization; 60° C. for 20 minutes	50.0	50
Formaldehyde, 1–240; 60° C. for 20 minutes	40.0	50
Average of checks	75.0	70

[a] Test carried on in quadruplicate (two dates of planting). Checks were used for every third row. Plan of experiment and types of treatment at Michigan Experiment Station, East Lansing, are shown in table 12. St. Louis tests were made on farm of Mr. Frank McLean.

be seen. On the third farm a field in which beets had always been unprofitable because of root rot and poor stand was planted partly with seed treated with copper carbonate, partly with seed treated with Semesan, and partly with untreated seed from the same sack as check. The Semesan and copper carbonate gave full stands, with Semesan slightly better than the copper carbonate. The untreated seed gave about two-thirds of a stand.

Single row plots in duplicate, with untreated seed every third row, were planted at St. Louis, Michigan, and at East Lansing. The plan of the experiment may be seen from table 11. Estimation of stand was made approximately two weeks after planting at both East Lansing and St. Louis.

Owing to damage by flooding, the field at St. Louis was not carried through to harvest, but the East Lansing plots were harvested and the results are given in table 12.

In the spring the Semesan dust plots at both East Lansing and St. Louis were best, with other mercury compounds and copper carbonate showing marked superiority over the untreated seed. Attempts to pasteurize seed and to combine pasteurization with a mercury treatment were not successful. Formaldehyde in all cases was the poorest of treatments. The copper dusts gave promise of giving a fair protection, ranking second to the mercury treatments.

The harvest records from the plots showed that the mercury bichloride treatment was first in respect to number of beets and total weight produced. Semesan and Du Pont Semesan 13 were approximately the same and approached the mercury bichloride treatment in effectiveness. The apparent contradiction with the earlier stand record can probably be attributed to the retarding effect that mercury bichloride has upon seedlings, delaying germination and checking growth at the outset. Copper carbonate, 50 per cent, ranked next to the mercury treatments and was better than the untreated seed in both numbers and weight.

DISCUSSION OF RESULTS

The writers believe the field tests just described to be in harmony with the previously outlined greenhouse tests and to demonstrate the applicability of these greenhouse tests to the determination of suitable seed treatments for sugar beets. But we do not believe that the practicability of seed treatment has been shown as yet.

On the other hand, we believe the experiences we have had in several years to be entirely typical of what is to be expected in seed treatments carried out as a commercial practice in Michigan. Damping off of seedlings does not occur in every field or in every season. In about one field in three or four we may expect to demonstrate some marked benefit from seed treatment. Of course in certain seasons, and with certain planting periods,

TABLE 12.—*Field tests with various sugar beet seed treatments[a] at East Lansing, Mich. Schreiber and Sohn seed planted in single rows in 25-foot plots, in quadruplicate*

Treatment	Number of beets per plot at end of test					Weight of beets in pounds					Rank based upon	
	A	B	C	D	Averages	A	B	C	D	Averages	Number	Weight
Untreated	14	12	18	16	15.00	17.50	20.00	28.50	21.00	21.75	–	–
Semesan, dust, 6 oz. per 15 lbs. seed	21	21	18	22	20.50	22.25	26.00	32.50	23.00	25.94	2	3
Dupont Semesan 13, dust, 6 oz. per 15 lbs. seed	15	18	20	20	18.25	20.75	23.50	28.75	31.00	26.00	3	2
Untreated	9	16	24	13	15.50	15.50	18.25	28.25	18.50	20.12	–	–
Large seed, untreated	14	14	16	14	14.50	20.75	21.25	21.75	20.00	20.94	–	–
Small seeds, untreated	13	17	16	22	17.00	17.50	23.50	25.00	25.00	22.75	–	–
Untreated	11	20	15	18	16.00	14.00	25.50	24.75	23.75	22.00	–	–
Copper carbonate, 18 per cent, dust	11	20	7	19	14.25	14.75	24.50	11.00	23.00	18.31	–	–
Copper carbonate, 50 per cent, dust	10	22	21	20	18.25	17.50	28.00	32.25	26.00	25.94	4	4
Untreated	11	15	15	13	13.50	23.00	19.25	32.00	26.00	24.06	–	–
Pasteurized, 60° C. for 20 minutes	2	20	6	15	10.75	5.25	27.00	16.25	24.50	18.25	–	–
Formaldehyde, 1–240; 60° C. for 20 minutes	2	20	12	8	10.50	4.50	28.00	23.25	11.25	14.75	–	–
Untreated	11	22	18	18	17.25	16.00	29.00	34.75	29.00	27.19	–	–
Mercury bichloride, 1–1000; 60° C. for 20 minutes	10	20	1	18	12.25	13.75	25.25	2.00	22.50	15.81	–	–
Mercury bichloride, 1–1000; 1 hour soaking, room temperature	25	21	22	24	23.00	28.75	21.25	45.50	28.00	30.88	1	1

TABLE 12.—*Continued*

Treatment	Number of beets per plot at end of test					Weight of beets in pounds					Rank based upon	
	A	B	C	D	Averages	A	B	C	D	Averages	Number	Weight
Untreated	7	25	21	15	17.00	11.50	29.00	30.75	19.00	22.31	–	–
Uspulun, 0.25 per cent; soaking 1 hour, room temperature	14	20	20	16	17.50	21.75	24.00	31.75	22.00	24.88	–	–
Copper sulphate-lime dust, 6 oz. per 15 lbs. seed	8	17	18	16	14.75	16.25	26.00	28.50	15.50	21.56	–	–
Untreated	10	18	21	15	16.00	19.50	23.25	32.00	19.50	23.56	–	–
Uspulun, 0.25 per cent; 60° C. for 20 minutes	11	20	18	12	15.25	19.00	22.50	28.25	14.00	20.93	–	–
Semesan, 0.25 per cent; 60° C. for 20 minutes	14	20	23	13	17.25	27.00	20.75	31.00	17.75	24.12	–	–
Untreated	5	—	19	11	11.66	17.00	——	30.50	17.50	21.66	–	–
Untreated	7	21	18	12	14.50	17.50	28.25	31.00	12.50	22.31	–	–
Average of untreated rows					15.2 ± 0.39					22.70 ± 0.55		

[a] Chemicals used were the same as given in tables with the exception of copper carbonate, 50 per cent, which was material prepared for cereal dusting by Riches and Piver, New York City.

The dusts were applied by churning in a barrel for 2 minutes approximately 10 pounds of seed and the requisite amount of dust.

The soaking treatments at room temperature were given in the ordinary manner and the seed spread out to dry. The treatments at 60° C. were given in large tanks of water heated by steam controlled by a hand valve. Temperature was held for the requisite time within 1° C. The seed was placed in thin cloth bags, loosely tied, and immersed in the water. Temperature readings were taken within the bags. The seed was dried over night by being spread out in thin layers.

damping off is very serious and then the gain from treatment would be large. Furthermore, certain of the seed treatments employed are entirely too costly at present prices of the chemicals. The soaking treatments seem to be completely precluded from practical use because of the difficulty of drying the seed balls in large quantities at the seed warehouses. When it is remembered that for the ordinary acreage of a factory nearly 100,000 pounds of seed would be handled, the impracticability of a wet treatment is obvious.

The writers believe that the application of dusting of sugar beet seeds with suitable disinfectants has great promise for the sugar beet industry. It seems that it is possible by the use of disinfectants to prevent in large part the serious reduction of stand which arises from the seed-borne pathogens. What is still more significant is the action of these disinfectants in actually warding off the pathogens so common in the soil, thus allowing the seedling to become established. If our opinion, that the root rots which develop late in the growing crop are the result of diseases contracted in the seedling stage, is correct, seed treatment of sugar beets may be of great value in preventing root rot losses.

While our experiments have not progressed far enough to permit recommendation of any compounds for general use, it is believed that progress has been made. The copper compounds we have tried do not seem effective enough to give the protection desired, and it seems safe to predict that some combination of mercury compounds with copper dusts will more nearly meet the need of a fairly cheap, effective dust for seed treatment.

SUMMARY

Seedling diseases of sugar beets, although often overlooked, cause serious losses in many sections. These seedling diseases are looked upon as especially important because of their relation to the diseases known as root rot, which develop on the half-grown and mature beets. Previous work has shown that *Phoma betae*, *Pythium debaryanum* and other Phycomycetes as well as *Rhizoctonia* spp. are the principal organisms causing seedling diseases of sugar beets in Europe and America. No practical control measures have been developed.

The seedling diseases studied have fallen into three general types, but assignment by field examination to a definite organism is hazardous.

Seed grown from carefully selected roots, kept under excellent storage conditions, and harvested by hand after growth in isolated plots, was found to be infested with *Phoma*, confirming the reports in the literature of the almost universal infestation of beet seed with this organism.

Greenhouse tests with muck soil and sandy loam soil showed that germination is reduced enormously by the beet pathogens and this reduction of stand increases if the soil is used repeatedly. Besides the loss before the

seedling emerges from the soil, there is a progressive loss in stand by damping-off of the seedlings during the period in which the true leaves are developing.

Pythium debaryanum was found to be the most common organism associated with diseased seedlings on muck soil, and it also was very prevalent in sandy loam soil. *Phoma betae* and *Rhizoctonia* were also isolated.

Tests with seedlings grown in sand showed that 33 per cent of the seedlings appearing above the surface of the sand may be killed by damping-off, *Phoma betae* being chiefly responsible, *Pythium* appearing but seldom. Ordinary plating methods may not indicate faithfully the etiological factors with diseases of this type.

Pasteurization at 60° C. for 10 minutes on two successive days proved to be a very effective treatment when pathogens of a soil source were absent, but of no value in infested soil, indicating that not only *Phoma betae* must be considered, but that *Pythium* and other organisms play their rôles in the damping-off complex.

Inoculation experiments showed that *Phoma betae* and *Pythium debaryanum* were both very strong and rapidly working parasites. *Rhizoctonia* sp. causes a high percentage of disease but is slower in producing its effects and leads to partially affected plants. Seed treatment was not effective with wholesale soil infestation.

The fungous content of the substratum and of the seed ball, rather than the physical nature of the soil, seemed to be the decisive factors in the incidence of disease.

Formaldehyde, furfural, nickel carbonate dust, and the proprietary compounds, Kalimat, Tillantin B, and Seed-O-San, were of little or no value under the conditions of our tests.

Pasteurization at 60° C. for 10 minutes, one day, or on two successive days, and dry heat, 93° C. or 110° C. for 10 minutes, failed to give protection with infested soil.

All of the tests are consistent in showing that mercury and copper compounds not only reduce the diseases arising from a seed source, but have more or less value in a protective action against diseases arising from the soil.

Semesan as a dust in excess and Dupont Semesan 13 in excess have been the leading dust treatments in greenhouse tests; and Chlorophol, 1–400; Uspulun, 1–400; and mercury bichloride, 1–1000, have given strong reduction of disease and stands far superior to the untreated seed.

Copper carbonate, 18 per cent, and copper sulphate-lime (50–50) dusts have given consistently fair control of disease and fair stands.

Field results have not been especially convincing, largely because favorable growing conditions have given good stands in the untreated plots in

spite of the disease factors. The general results indicate that the conclusions from the greenhouse experiments will be duplicated in the field tests.

Wet treatments are impractical for commercial use because of the difficulties inherent in drying the seed in quantity. The mercury treatments seem too costly to be practical. It is suggested that, since the dusts containing copper compounds have fair fungicidal value and are cheap enough to be practical, it may be possible to combine a copper dust with dusts containing mercury to obtain a cheap disinfectant having commercial possibilities.

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SULPHUR AS A CONTROL AGENT FOR COMMON SCAB OF POTATO

G. H. Duff and Catherine Graham Welch

In recent years efforts have been made to bring various pathogenic soil organisms under control by employing fungicidal materials as soil dressings. Among these materials sulphur has played a conspicuous role, particularly as a prospective agent for the control of common scab (actinomycosis) of potato. Since destructive diseases of this important crop have given indications of being amenable to sulphur treatment, the importance of a fuller understanding of the potentialities of this substance has not been lost on the industry. Generous support has therefore been forthcoming for the investigation of sulphur as a fungicide, and a fellowship for this purpose was allocated to one of the authors in 1922 by the Special Sulphur Fellowships Committee of the Division of Biology and Agriculture, National Research Council. To this Committee and to the Texas Gulf Sulphur Company of New York, the donor of the Fellowship, the authors are deeply indebted, not only for the opportunity afforded to study this important problem, but also for their cordial and helpful co-operation in many ways.

At the time this work was projected, very promising results had already been obtained by Martin (5) in New Jersey. The preliminary indications from Martin's work were that the incidence of scab could be considerably reduced by treating the soil with sulphur, and further that this control was brought about by acidification of the soil following the oxidation of the sulphur thus applied. The second conclusion appeared to be a confirmation of the work of Gillespie and Hurst (3) and of Gillespie (2) who found in the first place a correlation between soil acidity and the distribution of the potato scab organism in the field, and in the second place, that artificial culture media at or below pH 5.0 were very much less favorable for the cultivation of the organism than those of higher exponents. It appeared to these workers, therefore, that the control of the organism by sulphur dressings was dependent simply upon the attainment of a degree of acidity sufficient to inhibit its growth. This in turn is obviously dependent on the effective oxidation of the sulphur applied; and since the oxidation of sulphur in the soil has been shown by Lipman and his associates (4) to be mainly a biological process, there arose the expectation that sulphur inoculated with *Thiobacillus thiooxidans* would prove to be more effective as a control agent

than ordinary flowers of sulphur. This expectation seemed to be realized in the results of subsequent experiments by Martin (5).

The present authors felt that if these highly favorable and encouraging conclusions could be confirmed over a wide geographical area, a valuable contribution would have been made. Two major questions were envisaged:

1. Is sulphur equally effective in controlling potato scab on all soils and under all climatic conditions?
2. Is the lethal effect of sulphur upon *Actinomyces* always dependent solely, or even for the most part, upon the increased acidity following its oxidation in the soil?

A question of minor importance which was kept in view concerned the relative values of flowers of sulphur and of inoculated sulphur as control agents. This is obviously bound up with the second of the two major questions above.

In order to find answers to these questions, it was clearly necessary to conduct field trials with inoculated sulphur and with flowers of sulphur upon a number of soils varying as to type and history and well scattered geographically. It would have been quite impossible to do this had it not been for the cooperation of the Division of Botany, Experimental Farms Branch, Canadian Federal Department of Agriculture, the Ontario Agricultural College, and the Manitoba Agricultural College. Thanks to the admirable manner in which these institutions responded to our request, it was possible to conduct ten experiments in 1923 in important potato growing regions of Prince Edward Island, Nova Scotia, New Brunswick, Ontario, Manitoba, and Saskatchewan. One of these is not reported since the reliability of the results was made doubtful by irregularities in experimentation.

FIELD OPERATIONS

It was obviously impossible for the authors to give direct supervision to the field operations of every experiment. With the exception of the experiment at Guelph, which was thus supervised, each one was under the direction of some member of the staff in plant pathology of the Dominion Department of Agriculture or one of the agricultural colleges. Full and identical directions concerning the preparation of the land, the application of sulphur, planting, sampling of soils, making of notes, and lifting and classifying the crop were sent out to each of those concerned, in an effort to ensure uniformity of procedure. These directions were simplified in so far as possible in order to minimize the difficulty of adhering strictly to them. The authors were informed whenever, for any reason, the procedure deviated from that laid down in the directions. Towards the close of the season one of the authors made a tour of inspection, which included all the less remote

stations. This served as an assurance that the various field operations were being conducted in a manner that justified the comparison of results.

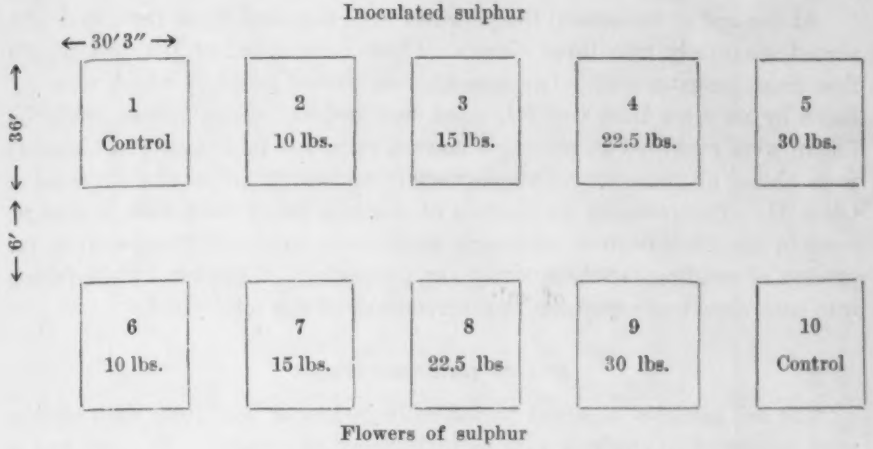

FIG. 1. Diagram of experimental plots.

Each field experiment consisted of ten plots, 1/40 acre in area, laid out and treated as shown in figure 1. The ground in each case was first worked up and the plots squared off. The first series of soil samples was then taken. The sulphur was broadcast immediately afterwards and raked in thoroughly, after which the potatoes were planted. The seed potatoes used were certified Irish Cobblers. These were cut as uniformly as possible and planted at a depth of 4 inches. The sets were separated in the rows by 15 inches and the rows themselves were 36 inches apart. In each plot 22½ lbs. of potatoes were planted, which is equivalent to a proportion of ten bags per acre.

The details of cultivation and of the employment of fungicides and insecticides were necessarily left to the officer in charge of the station, who employed the measures which experience had shown to be the most effective in his own locality. In point of fact these were not seriously different as between station and station, and such small differences in practice as there were do not invalidate the comparisons which will be made.

Soil samples were taken periodically and the sampling dates are, for the most part, shown in the tables. Six well-scattered samples were taken from the rows in each plot, the six mixed thoroughly and a final sample of about 250 grams taken from the mixture to represent the plot. These plot samples were at once put into separate cardboard cartons together with an identification card upon which were recorded notes concerning the growth of the crop, the incidence of diseases of the vines, the state of cultivation, etc.,

for the interval following the taking of the previous sample. The cartons were immediately posted to Toronto, where the acidity determinations were made.

At the end of the season the potatoes were dug and those from each plot sorted separately into three classes. Class I consisted of potatoes wholly free from common scab. In Class II were placed potatoes which were defaced by no more than two fair-sized scab lesions. Such tubers, while inferior, were regarded as bearing a market value for table use. In Class III were placed all those tubers which were more heavily infected than those of Class II. The presence or absence of diseases other than scab played no part in the classification, although notes were made of them during the process of grading. Subsequently the proportion of the total yield falling into each class was expressed as a percentage of the total yield.

ACIDITY DETERMINATIONS

The soil samples, received periodically in lots of ten, from each station, were subjected to analysis with as little delay as possible. The soil was at once air-dried and then passed through a sieve of .01 sq. mm. mesh. Fifteen grams of this sifted soil was then weighed into a centrifuge tube and 30 cc. of distilled water added to it. The tube was then shaken 75 times, after which the extract was cleared by centrifuging for five minutes at about 2500 r. p. m. Five cc. of the supernatant liquid were withdrawn into a narrow-bore test tube, five drops of indicator added and matched in a comparator against color standards of 0.2 pH intervals.

A few of the earlier acidity determinations were made from extracts which had been cleared by standing for 4 to 6 hours. When the centrifuge became available the two methods of clearing were compared upon the same soil samples, and the acidities resulting were found to check consistently. Thereafter the extracts were cleared exclusively by centrifugation.

For the purposes of the color standards McIlvaine's (1, p. 116) buffer mixtures were employed. These were carefully checked at frequent intervals by the hydrogen electrode, and renewed whenever necessary. The indicators used were those of Clark and Lubs (1, p. 80).

TABULATION OF RESULTS

Tables 1 to 9 summarize the results of the nine field experiments of 1923. Each table shows the ten plots involved in the experiment, their respective sulphur dressings, the total yield resulting, which is classified according to classes, and a record of the soil acidity throughout the season. Brief notes are given on the recent history of the soil with respect to lime and fertilizer dressings and to crops. Notes on the progress of growth and

TABLE 1.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Bedford, Prince Edward Island, in a sandy loam with red brick clay subsoil*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples					
	Type	Pounds per acre		I	II	III	May	June	July	Aug.	Early Sept.	Late Sept.
1	Inoculated sulphur	0	151	10.6	48.3	41.1	6.5	6.0	6.0	6.0	6.0	6.0
2		400	142	10.5	45.8	43.7	6.0	6.2	5.8	5.8	5.8	5.9
3		600	133	3.1	41.3	55.6	6.3	6.1	6.0	6.0	6.0	5.4
4		900	143	13.9	50.4	35.7	6.3	6.0	5.6	5.8	5.8	5.8
5		1200	132	9.4	34.4	56.2	6.0	6.1	5.2	5.7	6.0	5.3
6	Flowers of sulphur	400	143.0	8.5	46.8	44.7	6.0	6.2	6.0	6.0	6.0	5.8
7		600	151.0	3.9	45.6	50.5	6.2	6.2	5.8	5.2	5.8	5.8
8		900	166.5	2.4	40.5	57.1	6.4	6.3	5.5	5.7	5.7	5.9
9		1200	157.5	3.8	37.7	58.5	6.5	6.1	6.0	5.5	5.6	5.3
10		0	144.0	0.0	4.2	95.8	6.2	6.4	6.0	5.5	6.2	6.4

[a] In 1917 mussel mud (80–85 per cent lime) was applied to the soil at the rate of 10 tons per acre. The land was in potatoes in 1921 and scab was severe. In 1922 barley and clover were planted.

[b] *Field notes*: Growth was never better than fair during a late season. Blackleg appeared relatively early and was fairly uniformly destructive.

Rainfall.

June 2–23	1.28 inches	Aug. 2–Aug. 24	2.00 inches
June 23–July 13	2.75 do	Aug. 24–Sept. 20	3.95 do
July 13–Aug. 2	1.69 do	Weekly mean	0.71 do

TABLE 2.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at New Mills, Restigouche County, New Brunswick, in a sandy loam*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples					
	Type	Pounds per acre		I	II	III	May 30	June 20	July 19	Aug. 17	Sept. 5	Sept. 24
1	Inoculated sulphur	0	167.5	0.0	45.7	54.8	5.1	5.2	5.2	5.2	5.0	5.0
2		400	170.5	1.5	72.1	26.4	5.4	5.3	5.2	5.0	5.1	4.9
3		600	190.5	13.9	78.7	7.4	5.4	5.2	5.0	4.5	4.4	4.9
4		900	187.5	20.4	76.9	2.7	5.4	5.4	4.6	4.6	4.5	4.7
5		1200	159.5	6.9	82.2	10.9	5.4	5.8	4.6	4.5	4.4	4.6
6	Flowers of sulphur	400	88.5	20.3	64.5	15.2	5.1	5.0	4.8	4.4	4.6	4.6
7		600	120.5	12.2	65.9	21.9	5.4	5.4	5.0	4.4	4.6	4.7
8		900	153.5	9.1	76.8	14.1	5.4	5.4	4.7	4.7	5.0	4.5
9		1200	139.5	18.6	80.3	1.1	5.4	5.4	5.0	4.4	4.6	4.4
10		0	159.0	19.5	63.6	16.9	5.4	5.4	5.4	5.3	5.2	5.3

[a] In 1917 the soil was limed with fish and seaweed (200 pounds per acre) and subsequently has been dressed frequently with lobster, clam shells, and other calcareous material. The land was in potatoes for several years. Scab was invariably present and was severe in 1922.

[b] *Field notes*: Growth was fair, with a few misses and a small number of plants developing mosaic, leafroll, and blackleg. Plots 1–5 seemed to get a better start than plots 6–10 and contained fewer weak plants. This initial superiority was maintained and reflected in the yield. Tubers showed traces of rhizoctonia, blackleg, and silver scurf.

TABLE 3.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Sackville, New Brunswick, in a sandy loam*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples					
	Type	Pounds per acre		I	II	III	May 29	June 19	July 14	Aug. 6	Aug. 28	Sept. 13
1	Inoculated sulphur	0	265	26.4	65.3	8.3	5.6	5.2	5.6	6.0	5.6	6.0
2		400	322	24.8	71.8	3.4	5.6	5.0	4.9	5.6	6.4	4.7
3		600	377	26.2	72.9	0.9	5.5	4.9	4.6	4.8	5.0	4.4
4		900	362	21.8	75.9	2.3	5.2	4.4	4.0	4.0	4.6	3.7
5		1200	342	13.7	78.2	8.1	5.1	5.2	4.0	4.0	3.8	4.0
6	Flowers of sulphur	400	415	20.2	78.5	1.3	5.2	5.1	5.2	5.2	5.0	5.0
7		600	368	20.7	77.9	1.4	5.4	5.6	5.0	4.6	4.9	4.9
8		900	468	6.8	85.7	7.5	5.1	5.0	4.0	4.6	4.6	4.8
9		1200	397	3.3	81.3	15.4	5.0	4.6	4.0	4.2	4.0	4.4
10		0	378	10.1	79.6	10.3	5.0	4.8	5.3	5.2	5.3	5.2

[a] The land was in sod for 7 years prior to 1921, and had never been limed. In 1921 and 1922 the potato crop was unfit for the market on account of scab.

[b] *Field notes*: Plants were vigorous and healthy during most of the growing season, although slightly affected by late blight. Tubers showed traces of late blight and blackleg.

Rainfall.

May 29–June 19	1.26 inches	Aug. 6–Aug. 28	1.18 inches
June 19–July 14	2.99 do	Aug. 28–Sept. 13	0.35 do
July 14–Aug. 6	2.62 do	Weekly mean	0.53 do

TABLE 4.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Plaster Rock, Victoria County, Nova Scotia, in a sandy loam*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples					
	Type	Pounds per acre		I	II	III	May 29	June 19	July 10	July 31	Aug. 21	Sept. 28
1	Inoculated sulphur	0	405.0	96.2	2.5	1.3	5.0	5.4	5.6	5.4	5.2	4.9
2		400	310.0	98.0	1.6	0.4	5.1	5.3	5.4	5.2	5.2	4.4
3		600	330.0	97.8	1.3	0.9	5.2	5.2	5.0	4.8	4.4	3.5
4		900	295.5	99.0	0.4	0.6	5.0	5.2	5.0	4.8	4.0	3.6
5		1200	265.0	99.6	0.4	0.0	5.4	5.0	4.6	4.8	3.8	3.4
6	Flowers of Sulphur	400	510.0	98.4	0.6	1.9	5.4	5.5	5.2	5.1	5.2	4.7
7		600	360.0	94.6	4.2	1.2	5.1	5.3	5.2	5.1	5.0	4.8
8		900	425.0	97.5	1.2	1.3	5.2	5.4	5.0	5.2	5.1	4.6
9		1200	390.5	95.5	3.6	0.9	5.0	5.3	5.0	5.2	5.0	4.5
10		0	273.0	97.0	1.8	1.2	5.1	5.3	5.4	5.4	5.2	5.2

[a] The land was in hay for several years prior to 1923 and had never been limed.

[b] *Rainfall.*

May 29–June 19	0.10 inches	July 31–Aug. 21	1.33 inches
June 19–July 10	1.58 do	Aug. 21–Sept. 28	2.52 do
July 10–July 31	3.13 do	Weekly mean	0.49 do

TABLE 5.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Central Experimental Farm, Ottawa, Ontario, in a clay loam*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples				
	Type	Pounds per acre		I	II	III	June 1	June 21	July 14	July 31	Aug. 27
1	Inoculated sulphur	0	386	99.1	0.9	0	6.2	6.0	5.8	6.1	6.2
2		400	450	98.1	1.9	0	6.2	6.0	6.0	6.0	6.0
3		600	496	98.8	1.2	0	6.1	6.0	5.9	5.3	5.8
4		900	549	96.3	3.7	0	6.2	6.0	6.0	5.5	5.2
5		1200	585	97.6	2.4	0	6.2	5.9	6.0	5.0	5.0
6	Flowers of sulphur	400	376	98.5	1.5	0	6.1	5.9	5.5	5.7	5.6
7		600	272	98.9	1.1	0	6.0	6.0	5.6	5.6	5.4
8		900	486	96.8	3.1	0.1	6.2	5.8	5.9	5.5	5.0
9		1200	495	88.7	11.3	0	6.2	5.6	6.0	5.0	4.9
10		0	535	97.1	2.9	0	6.2	6.0	6.0	6.0	6.0

[a] Prior to 1923 a variety of crops had been grown: grass, oats, buckwheat, and truck crops.

[b] *Field notes:* Growth was good on the whole, but there were misses, on account of excessive soil moisture, which were sufficiently serious in number to affect the figures for yield. Leaf roll present, but in only two or three plants.

Rainfall:

June 1–June 21	3.42 inches	Aug. 6–Aug. 27	1.99 inches
June 21–July 14	3.53 do	Aug. 27–Sept. 17	3.42 do
July 14–Aug. 6	1.93 do	Weekly mean	0.95 do

TABLE 6.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Ontario Agricultural College, Guelph, Ontario, in a clay loam*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples					
	Type	Pounds per acre		I	II	III	May 25	June 16	July 7	July 28	Aug. 18	Sept. 8
1	Inoculated sulphur	0	166.0	0	0.4	99.6	7.2	7.4	7.0	7.0	7.0	7.0
2		300	162.5	0	6.5	93.5	7.2	7.1	6.6	6.8	6.9	6.9
3		600	168.0	0	6.9	93.1	7.2	7.0	6.7	6.6	6.8	6.8
4		900	168.0	0	4.8	95.2	7.2	6.7	6.5	6.6	6.4	6.6
5		1200	162.5	0	4.9	95.1	7.2	7.1	6.6	6.6	7.0	6.7
6	Flowers of sulphur	300	101.5	0.6	28.5	70.9	7.2	7.2	7.2	7.0	7.0	7.0
7		600	142.5	0.3	19.6	79.6	7.2	7.0	7.0	6.8	7.0	7.0
8		900	138.0	0.2	12.3	87.5	7.2	6.7	6.5	6.8	6.8	6.8
9		1200	141.5	0.6	27.2	72.2	7.2	6.8	6.3	6.2	6.4	6.6
10		0	166.5	0.0	2.2	97.8	7.2	7.5	6.8	7.1	7.0	7.0

[a] The soil had never been limed. In 1920 the potato crop was slightly affected by scab. The land was in clover and mangels in 1921 and 1922.

[b] *Field notes*: Growth of the plants was uniformly good. The only disease appearing was tip-burn which was noted first in the middle of August. Rhizoctonia present at digging.

Rainfall:

May	4.00 inches	Aug.	4.86 inches
June	4.46 do	Sept.	3.14 do
July	3.11 do	Weekly mean	0.91 do

TABLE 7.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Devlin, Rainy River District, Ontario, in a heavy clay*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples				
	Type	Pounds per acre		I	II	III	May 22	June 18	July 10	July 31	Aug. 21
1	Inoculated sulphur	0	560	18.1	81.9	0	7.4	7.4	7.4	7.4	7.4
2		400	554	31.1	68.9	0	7.4	7.4	7.2	7.3	7.4
3		600	558	50.6	49.4	0	7.4	7.2	7.0	7.2	7.0
4		900	543	75.1	24.9	0	7.4	7.4	7.0	7.1	7.2
5		1200	547	69.1	30.9	0	7.4	7.6	7.0	7.0	6.7
6	Flowers of sulphur	400	538	69.6	30.4	0	7.4	7.4	7.0	7.2	7.0
7		600	579	83.2	16.8	0	7.4	7.3	7.2	7.2	7.3
8		900	572	73.5	26.5	0	7.4	7.2	6.7	7.2	7.4
9		1200	563	69.5	30.5	0	7.4	7.2	6.8	7.3	7.2
10		0	587	33.3	66.7	0	7.4	7.4	7.3	7.4	7.4

[a] No lime or fertilizer has ever been applied to the soil. In 1919 the potato crop was severely affected by scab. The land was in clover in 1920–1922.

[b] *Field notes*: Growth of the plants was uniformly good and they remained free of disease.

Rainfall:

May	0.47 inches	Aug.	1.12 inches
June	2.55 do	Sept.	2.37 do
July	2.94 do	Weekly mean	0.43 do

TABLE 8.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Manitoba Agricultural College, Winnipeg, in well-drained, black, Red River Valley clay*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples					
	Type	Pounds per acre		I	II	III	May 25	June 13	July 9	July 30	Aug. 4	Sept. 12
1	Inoculated sulphur	0	156.5	48.3	49.8	1.9	6.6	6.6	6.6	6.6	6.6	6.4
2		400	163.0	65.3	33.2	1.5	7.3	7.1	6.4	6.0	6.4	6.1
3		600	86.0	75.5	23.3	1.2	6.6	6.5	6.0	6.0	6.2	5.8
4		900	55.0	81.8	16.8	1.4	7.4	6.8	6.6	6.2	6.2	5.6
5		1200	71.0	85.9	14.1	0.0	6.8	6.6	6.0	6.0	6.0	5.4
6	Flowers of sulphur	400	183.0	60.4	37.9	1.7	6.6	6.6	6.3	6.3	6.6	6.0
7		600	155.5	59.7	39.9	0.4	6.6	6.3	6.0	6.0	6.7	6.0
8		900	93.0	79.6	20.4	0.0	6.5	6.0	5.9	6.0	6.1	5.0
9		1200	110.5	80.9	18.6	0.5	6.8	6.3	5.9	6.0	6.0	5.5
10		0	136.0	46.3	49.6	4.1	6.6	6.6	6.6	6.6	6.7	6.4

[a] The sod was newly broken in 1921, and has never been limed. Potatoes grown in 1921 were slightly affected by scab. The land was in wheat in 1922.

[b] *Field notes:* Growth throughout the season appeared to be good for the most part, although early dry weather resulted in retardation of individual plants here and there. A small number of plants were affected by leaf roll. Tubers showed rhizoctonia and black scurf.

Rainfall:

May	2.55 inches	Aug.	0.65 inches
June	1.47 do	Sept.	1.09 do
July	3.55 do	Weekly mean	0.42 do

TABLE 9.—*The effect of sulphur on the incidence of common scab on potatoes grown in 1923 at Rosthern, Saskatchewan, in a well-drained, black, sandy prairie loam with 6–18 inches of impervious clay subsoil*[a]

Plot no.	Sulphur		Total yield in lbs.[b]	Yield in each class in per cent			pH of soil samples				
	Type	Pounds per acre		I	II	III	June 6	June 28	July 17	Aug. 7	Aug. 29
1	Inoculated sulphur	0	517	8.3	76.9	14.8	6.0	6.0	6.0	6.2	6.0
2		400	538	8.7	77.6	13.7	6.0	6.0	6.0	5.8	5.8
3		600	533	10.2	83.5	6.3	6.0	5.8	5.8	5.8	5.9
4		900	570	12.4	85.3	2.3	6.0	6.0	6.0	5.9	6.0
5		1200	505	22.9	75.7	1.4	6.0	6.1	6.0	5.9	5.8
6	Flowers of sulphur	400	587	13.5	84.8	1.7	6.1	5.8	6.0	6.0	6.0
7		600	537	13.1	72.8	14.1	6.1	5.8	6.0	6.2	6.0
8		900	546	12.5	70.9	16.6	6.1	6.2	6.0	6.2	6.0
9		1200	494	3.1	71.2	25.7	6.0	6.0	6.0	6.0	6.0
10		0	400	4.5	64.3	31.2	6.0	6.0	6.0	6.0	6.0

[a] The soil was broken about 1913, and has never been limed. The land was in oats in 1921 and lay fallow in 1922.

[b] *Field notes*: Growth began unevenly and slowly under dry conditions but by the middle of July it was good. Blackleg and rhizoctonia appeared early in a few plants and later on there were traces of blight.

Rainfall:

June 6–June 28	2.90 inches	Aug. 7–Aug. 29	1.52 inches
June 28–July 17	1.95 do	Weekly mean	0.71 do
July 17–Aug. 7	2.87 do		

the incidence of disease throughout the season, and data on rainfall have been given where these were available.

ANALYSIS OF RESULTS

Attention may now be directed to the questions chiefly under consideration, namely, whether or not sulphur is equally effective in control under various conditions of soil and climate and whether or not the adverse effect of sulphur upon the disease is merely a function of its effect upon the acidity of the soil. To do this it is necessary to decide in which experiments there were indications of satisfactory control and in which ones sulphur applications resulted in significant increases in soil acidity as measured by the hydrogen-ion concentration of watery extracts.

The only results which might be considered to give any sort of indication of successful control are those at Devlin and Winnipeg (Tables 7 and 8), where there were substantial increases in the proportions of clean tubers, and those at New Mills and Sackville (Tables 2 and 3), where the proportions of slightly infected tubers (Class II) were large. In the latter two, however, either one or both control plots produced crops with sufficiently large proportions of Class II tubers to make insignificant the increases shown in the experimental plots. It must be concluded, therefore, that the only experiments which offered unequivocal and satisfactory indications of control were those at Devlin and Winnipeg. In these experiments sulphur applications brought about substantial and roughly proportional increases in the percentages of clean tubers, and with the higher applications led to crops in which the vast majority of the potatoes were free from scab. Nothing less definite than this can be considered a satisfactory or successful result.

Before pointing out any apparent correlations between successful control on one hand and factors of soil and climate on the other, we must first enquire whether factors other than these could have determined the conclusion that the experiments at Winnipeg and Devlin were the only ones successful in control. In the first place the circumstance that the crops at the various experimental centers were not graded by the same person might be supposed to introduce an important source of error. The scheme of grading was very simple, however, dependent at its most critical point (the distinction between potatoes infected and those not infected with scab) solely upon the ability to recognize common scab. Since all the field collaborators were thoroughly familiar with diseases of the potato, it is hardly possible that the conclusion drawn could have resulted from lack of uniformity in grading.

A more serious point is the one very properly emphasized by Roach, Glynne, Brierley, and Crowther (7) in their admirable paper on the control

of potato wart disease, namely, the thoroughness of the incorporation of the sulphur with the soil. It is obvious that the employment of the same procedure in each case will not bring about the same state of incorporation of the sulphur in wholly different soils. Furthermore, in two of the present experiments the method of incorporation differed from that employed in the others. At Guelph the sulphur was worked in by the harrows, and at Winnipeg after planting by hoeing and cultivating. The authors are, therefore, not in a position to say that the sulphur was equally well incorporated in all the experimental plots here compared. Assuming, however, that the more intimate the admixture of sulphur the greater its effect upon the organism, it is interesting to note that the only two experiments in which a satisfactory degree of control was obtained were those wherein, for different reasons, a relatively poor state of incorporation might have been expected. At Winnipeg the method of working in the sulphur can hardly have been as effective and certainly not more so than that employed elsewhere. At Devlin the soil is a heavy and intractable clay into which, using the same method, it would be considerably more difficult to incorporate the sulphur than into a sandy loam soil. Moreover, the great differences in the degree of control attained at Winnipeg and Bedford, for instance (Tables 8 and 1), would appear to postulate improbable differences in the state of incorporation of the sulphur, interpreted on that basis alone.

TABLE 10.—*A summary of the effectiveness of sulphur in controlling common scab on potatoes grown in nine different localities of Canada in 1923*

Location of experiment	Control	Depression of pH	Soil type	Lime	Rainfall index
Plaster Rock	Organism absent or	5.1–3.4	Sandy loam	None	0.49
Ottawa	non-virulent	6.1–4.9	Clay loam	do	0.95
Winnipeg	Positive	6.7–5.4	Clay	None	0.42
Devlin	Positive	7.4–6.7[a]	Clay	None	0.43
Bedford	Negative	6.2–5.3	Sandy loam	1917	0.71
New Mills	do	5.3–4.4	Sandy loam	1917–1922	.....
Sackville	do	5.4–3.7	Sandy loam	None	0.53
Guelph	Negative	7.1–6.2[a]	Clay loam	None	0.91
Rosthern	do	6.0–5.8[a]	Sandy loam	None	0.77

[a] An insignificant acidity increase. Figures in the column "Depression of pH" were derived as follows: The first figure is the average of all determinations upon untreated soil, and the second is the lowest single exponent obtained in each experiment. For further details tables 1 to 9 should be consulted.

A third consideration has to do with the prevalence of virulent strains of the scab organism in the soil at the beginning of the experiment. Judging from the percentage of infected tubers in the control plots, this is obviously very different in the various experiments with which we are dealing. It is also clear that in the two experiments most successful in the matter of control, the soil was not so heavily infested as in those which were unsuccessful.

When we come to the factors of soil and climate and their influence in control, two points of interest arise: the first is that both soils which gave an encouraging degree of success were clay soils. The second is that the rainfall was lower at these than at any other experimental points and considerably lower than at most of them.

The considerations under discussion are brought together in table 10, in which the "rainfall index" is the weekly mean rainfall for the season at each experimental point (see tables 1 to 9). Since soil moisture determinations were out of the question and because all the experimental plots were adequately drained, it was felt that this index yielded a convenient, if rough, measure of the moisture factor.

The results, in so far as control is concerned, may be summarized from table 10 in these terms: With the methods here employed, sulphur was not uniformly effective under all conditions of soil and climate, but gave encouraging results only upon clay soils, infested in but moderate numbers or by attenuated strains of the organism and under conditions of low moisture

Tables 1 and 9 reveal a conspicuous absence of any constant relationship which might have been expected between control and soil acidity. Failure to bring about satisfactory indications of control is not invariably coupled with failure to bring about a significant increase in soil acidity; and, conversely, plots in which no significant acidification has taken place have, in one experiment (Table 7), shown satisfactory evidences of control. These apparent inconsistencies are interesting inasmuch as they suggest strongly that the problem of control is not a simple one, bound up only with the effect of sulphur upon the soil acidity, but that these two effects may, under appropriate conditions, be quite independent.

In most of the experiments, sulphur dressings resulted in measurable increases of acidity, which, however, vary in magnitude from the merest indication of change (Table 7) to very marked depressions of the pH resulting in acidities considerably greater than that indicated as the limiting acidity for *Actinomyces* by other workers (Tables 3 and 4). In one experiment (Table 9) no sensible change whatever seems to have been effected. Obviously, very small or irregular changes, and those which do not result in acidities approximating the limiting value referred to, cannot be regarded as significant, in this sense, that either by comparison with the others they

are wholly incommensurate with the quantities of sulphur applied, or they do not result in a pH sufficiently low to lead to any expectation of control on that ground alone. For present purposes, we may regard any pH lower than 5.5 as approximating the limiting value for *Actinomyces*. On this hypothesis, the experiments at Guelph, Devlin, and Rosthern (Tables 6, 7, and 9) are the only ones characterized by insignificant acidity changes.

Of these three soils, sulphur had the least effect at Rosthern, while at Devlin and Guelph the acidification was definite, although the lowest pH obtained was not significant for control. In order to see whether excessive alkali reserves were responsible for the behavior of these soils toward sulphur, carbonate determinations were made by the Parr method. The results expressed as percentages of calcium carbonate are given in table 11. It is

TABLE 11.—*The relation of carbonate content of the soil to slight increases in soil acidity produced by applications of sulphur*

Location of experiment	Depression of pH	Percentage $CaCO_3$
Rosthern	6.0 to 5.8	0.205
Devlin	7.4 to 6.7	0.337
Guelph	7.1 to 6.2	3.370

clear that at Guelph the carbonate content of the soil may be the cause of the small change in acidity. From the initial acidity of the soil this was hardly to have been expected at Rosthern. But at Devlin, where some success in control was attained, the smallness of the change in acidity is not accounted for by the carbonate content of the soil.

Now, having regard only to the relationship between acidity and control, there are five ways in which any one of the experiments could have resulted: any given experiment might have been disqualified for the purposes of discussion by the absence of a virulent strain of the organism, or it might have resulted in any one of the four possible combinations of presence or absence of satisfactory control with presence or absence of significant acidity increase. Table 10 demonstrates the fact that all of these possibilities were realized in this series of experiments and argues strongly for the independence of the two effects of sulphur under these conditions.

No obvious differences were noted between the two forms of sulphur in respect of their effect either in control or in acidification of the soil. At Plaster Rock (Table 4) inoculated sulphur gave a slightly better acidification than flowers of sulphur, but this situation is reversed at Ottawa and Winnipeg (Tables 5 and 8). At Devlin (Table 7) plots treated with flowers of sulphur appear to have yielded slightly higher percentages of clean tubers than plots treated with inoculated sulphur. All these differences are incon-

siderable, however, and the conclusion indicated would seem to be that neither form of sulphur had any constant advantage over the other.

SUMMARY

1. In these experiments sulphur was not uniformly effective in controlling common scab under all conditions of soil and climate, but gave encouraging results only upon clay soils infested by moderate numbers or by attenuated strains of the organism and under conditions of light rainfall.
2. Evidence is offered of the independence of the effect of sulphur upon soil acidity and its effect upon the disease.
3. No significant difference was observed between inoculated sulphur and flowers of sulphur in respect either of control or of soil acidification.

It would be impossible for the authors to name individually all those to whom they are obligated for the help that made these experiments possible, but especial mention must be made of Mr. H. T. Güssow, Dominion Botanist; Professor J. E. Howitt, Ontario Agricultural College; and Dr. G. R. Bisby, Manitoba Agricultural College. To these gentlemen we are indebted for field facilities, supervision of field operations and many other courtesies. Mr. S. Waterman, of the Ontario Agricultural College, very kindly made the carbonate analyses. To Professor J. H. Faull we owe our thanks for his keen and stimulating interest in the work at all times, and for valuable suggestions and assistance.

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A METHOD FOR TESTING IN VITRO THE TOXICITY OF DUST FUNGICIDES TO FUNGOUS SPORES

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INTRODUCTION

Eye spot is a leaf disease of sugar cane caused by the fungus *Helminthosporium* (*Cercospora*) *sacchari* Butler. Upon very susceptible cane varieties and under favorable conditions for the development of the disease, lesions frequently become so numerous in the young growing spindle that the entire top dies, thus producing a top rot of individual stalks. Material losses are therefore caused by eye spot in small areas in localities where climatic conditions are favorable to the disease.

The application of liquid fungicidal sprays to sugar cane in the usual large fields of most countries is not economically feasible because of the matted and impassable growth of the cane. Under these conditions, however, dust fungicides were found to be readily and cheaply applicable both in field and plot tests in the Hawaiian Islands (4). In field plot tests, with adequate replications, plots treated with Bordeaux dust showed no decrease of eye spot over the control plots. Plots dusted with sulphur showed a slight improvement over untreated plots but the treatment was far from being completely effective. Attempts have therefore been undertaken to secure more effective dust fungicides against the eye-spot fungus, and the following laboratory tests have been developed.

In looking through the literature for similar methods, a procedure suggested by Reddick and Wallace (5) has been noted: it consists of spraying microscope slides with the fungicide to be tested and subsequently placing spores of the fungus on the slide and comparing germination with that of spores on untreated slides. It would seem as if this method was the more feasible for organisms which are cultured with difficulty, but that the method outlined in the present paper is less tedious and more accurate for fungi which are cultured easily. The tests are quicker and also cheaper than field tests. We have used these tests, however, as a preliminary step in selecting new fungicides for subsequent field tests. As we regard them, these tests are an adjunct to field tests of fungicides and should not be considered as a method to supplant field tests.

DESCRIPTION OF THE METHOD

The original plan of the test was taken from the method of determining the phenol coefficients of disinfectants originated by Anderson and McClin-

tic (1). This method was modified slightly by Lee (3) to determine the effect of disinfectants against bacterial plant pathogenes. With considerable modifications, it is now being used to determine the effect of dust fungicides against fungi.

Source of Fungous Material to be Tested. The fungus, which is the eye-spot fungus in this case, is cultured in petri dishes on standard nutrient agar plus 2 per cent glucose, pH 7.0, prepared according to the Committee on Bacteriological Technic (2). Cultures are usually maintained at 25° C. in total darkness for nine or ten days, when dense masses of spores are available. It is essential to have the cultures used in the test grown under standardized conditions as nearly as possible.

Apparatus Used. Small round cover glasses, 15 mm. in diameter, are placed in rows on the bottom of glass moisture chambers about 20 centimeters in diameter; these we call, for convenience, dusting chambers. We usually have 50 or 60 such cover glasses to each dusting chamber. The dusting chambers with the enclosed cover glasses are sterilized with moist heat in an autoclave. A suspension of spores from the standardized petri dish cultures of the eye-spot fungus is then prepared in sterile water. Drops of this suspension are examined under the microscope so as to secure 15 to 20 of the fungous spores in a drop. With a sterile 3-mm. platinum loop, one drop of this spore suspension is placed on each of the round cover glasses in the sterilized dusting chambers. All work is carried on in the transfer room and all precautions are taken to avoid contamination of the cover glasses and moisture chambers.

Procedure. The cover of one of the dusting chambers is lifted sufficiently to allow a small insuflator or puff gun[1] to be operated, and a light application of the fungicidal dust to be tested is applied to the 50 or 60 cover glasses having the drops of the spore suspension. We recently have been weighing 2 grams of the dust being tested into the puff gun and expending the total amount in one dusting chamber, so that the amounts of each dust tested are identical. The glass cover of the dusting chamber is then replaced and, following the dusting at time intervals of ¼, ½, 1, 2, 3, 4, 6, 10, 12, 24, and 48 hours, five of the dusted cover glasses are removed with sterilized forceps and other aseptic precautions. Each cover glass,

[1] Since this paper was written, Dr. C. R. Orton, at the Boyce Thompson Institute, has shown the writers a device which is superior and more accurate than the puff gun. It consists of an ordinary culture tube, corked, with a blow tube extending through the cork to the bottom of the culture tube. A short outlet tube extends through the cork. When one places the mouth or an ordinary rubber pressure bulb at the end of the blow tube and forces air into the culture tube, the fungicidal dust at the bottom is expelled through the outlet tube and can be directed easily into the dusting chamber. This apparatus is much more easily cleaned and is more accurate than the puff gun.

when it is removed from the dusting chamber, is immediately placed in a culture tube containing 10 cc. of sterile nutrient bouillon.

If the fungous spores are unaffected by the fungicidal dust, growth will occur in the bouillon tubes within two to four days; whereas, if the dust has been toxic to the fungous spores, no growth will result. Working with one fungus such as *Helminthosporium sacchari*, with experience one can instantly recognize contaminations in the bouillon culture tubes. With adequate precautions contaminations are not common.

One cannot be sure that the suspension on the cover glasses contains spores only and no mycelium, but since the mycelium is more quickly affected by the dust than the spores the time interval necessary to prevent growth in the bouillon tubes represents the toxicity to the spores rather than to the mycelium. More recently also our method of obtaining the spore suspension has been to pour the water from a 10 cc. sterile water blank into a 10-day-old culture of the fungus. The spores are then floated off and the suspension pipetted back into a sterile culture tube having a minimum of mycelium as compared to the quantity of spores.

The time intervals for exposure of the fungous spores to the dust may be varied in different tests, according to the discretion of the investigator.

One undusted chamber of 60 inoculated cover glasses is maintained as a control; and whenever dusted cover glasses are placed in the bouillon tubes, five undusted cover glasses are removed to five bouillon tubes as controls. In our laboratory we have usually run tests of four or five different dusts at the same time, with a separate chamber for the undusted controls.

Results. To illustrate the nature of the tests and the results, a few representative trials are presented in tables 1 and 2.

TABLE 1.—*The fungicidal action of various dust preparations on spores of Helminthosporium sacchari*

Treatment, Oct. 2, 1924	Time of exposure in hours						
	1	4	10	12	24	30	46
	No. of bouillon tubes[a] in which growth of the fungus occurred, Oct. 11, 1924						
Control	5	5	5	5	5	5	5
Calcium hydrate	5	5	5	4	4	3	1
Du Pont No. 1	5	5	5	4	4	2	3
Du Pont No. 12	0	0	0	0	0	0	0
Du Pont No. 13	5	5	5	3	0	0	0
Du Pont No. 18	3	2	0	0	0	0	0

[a] In each test five inoculated cover glasses were exposed and transferred to five tubes of sterile bouillon.

The results in table 1 indicate that spores of the eye-spot fungus were killed in one hour by Du Pont dust no. 12, in ten hours by Du Pont dust no. 18, and in twenty-four hours by Du Pont dust no. 13. Du Pont dust no. 1 did not kill the spores readily in forty-six hours; and calcium hydrate, although minimizing germination in forty-six hours, did not inhibit spore germination completely in this test.

Confirmatory results with the same fungicides are shown in table 2.

TABLE 2.—*The fungicidal action of various dust preparations on spores of Helminthosporium sacchari*

Treatment, Oct. 29, 1924	Time of exposure in hours					
	¼	½	1	2	4	7
	No. of bouillon tubes[a] in which growth of the fungus occurred, November 3, 1924					
Controls	5	5	5	5	5	5
Du Pont no. 1	5	5	5	5	5	5
Du Pont no. 12	0	0	0	0	0	0
Du Pont no. 13	2	2	2	1	0	1
Du Pont no. 18[b]	3	1	0	0	0	0

[a] In each test five inoculated cover glasses were exposed and transferred to five tubes of sterile bouillon.

[b] Although Du Pont dusts No. 12 and 18 have been very toxic to the eye-spot spores, their use on a commercial scale has not yet been tried in field plot experiments.

DISCUSSION

Since the tests tabulated above were made, we have tried out numerous fungicidal dust preparations by these methods. In those cases where we have followed up such tests *in vitro* with field plot tests, the field results have corroborated the laboratory tests with one exception.[2] In vitro the drop of spore suspension usually dries up in from six to twelve hours; and it may be argued that, with the spores dry and none of the fungicide in solution, there will be no action of the fungicide. However, almost identical conditions exist in the fields where eye spot occurs. Under field conditions, the dust is applied to the cane in the early morning while moisture is still on the leaves; in from four to six hours the dew has disappeared and the leaves are dry.

This method indicates the toxicity of the fungicides only in the absence of organic matter, but the results are, of course, comparative.

[2] Sulphur *in vitro* did not affect spores of the eye-spot fungus, but in field plots treated with sulphur dust there was a slight reduction of eye-spot as compared with untreated plots.

It may be possible to present the results of further tests in a subsequent paper.

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RINGSPOT OF TOBACCO; AN INFECTIOUS DISEASE OF UNKNOWN CAUSE[1]

F. D. Fromme, S. A. Wingard and C. N. Priode

INTRODUCTION

Our knowledge of the ringspot disease of tobacco dates from 1917, when we observed it for the first time in fields at South Boston, Virginia. The disease was well-known locally at that time and was commonly called ring worm, in the belief that it was caused by insects. We were engaged then and for several succeeding years in a study of blackfire of tobacco, and only occasional notice was given to ringspot. Recently we have devoted more study to this disease and have demonstrated it to be of an infectious nature. Dr. W. D. Valleau informs us that he has obtained similar proof, and at his suggestion we are publishing some phases of our studies at this time.

The disease was first described and illustrated under the name of ringspot by Fromme and Wingard (1) in 1922, and it was discussed in some

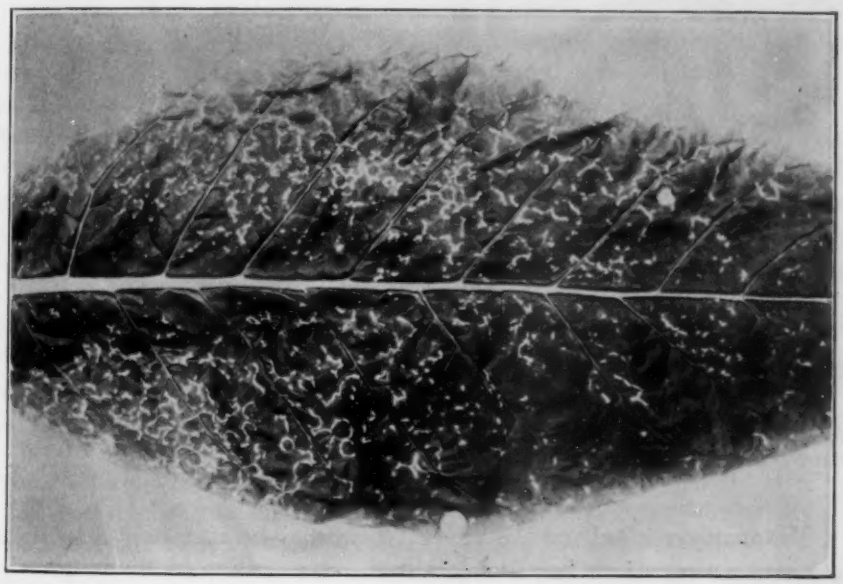

Fig. 1.—Leaf of burley tobacco affected with ringspot. Many of the rings are broken. Natural infection. Appreciably reduced.

[1] Paper No. 69 from the Department of Botany and Plant Pathology, Virginia Agricultural Experiment Station.

further detail by Wingard and Godkin (7) in 1924. It was considered a non-parasitic disease at this time. Johnson (2) also published figures of a leaf-spot similar to ringspot which he considered non-parasitic, and a figure which was published by Selby (4, plate 1, p. 89) in 1904 strongly suggests the ringspot disease, although it is labeled tobacco mosaic. There is no description in the text of Selby's bulletin which would indicate that a distinct disease of the ringspot type had been recognized. The occurrence of ringspot (also called heiroglyphics) in Virginia, Kentucky and Ohio in 1922 was reported by the Plant Disease Survey in 1923 (5, p. 142), and a further record of occurrence in Kentucky appeared in 1924 (6, p. 295).

OCCURRENCE

At the present time, ringspot occurs quite commonly in the tobacco sections of Virginia, and it has probably been present in the State for a number of years. In a survey of tobacco fields in 1920 it was found in 80 per cent of the fields in Fluvanna County and in 30 per cent of those examined in Charlotte County. It occurred in 1922 in 17 of 28 fields visited in Charlotte County, and we have definite records in this and other years of its presence in Amherst, Bedford, Campbell, Caroline, Halifax, Henry, Pittsylvania, Prince Edward, Russell, and Washington Counties.

The incidence of infection is usually low, and there often are only a few affected plants, in restricted areas of the field. In other fields, however, the incidence of infection has been rather high and severe injury has resulted. An infection of 30 per cent of the plants was noted in several fields in Charlotte County in 1922, and losses in these were appreciable. Some plants have practically all of the leaves affected, while others may show only a spot or two on a single leaf. A severely infected plant may be dwarfed and the leaves may be small, light in weight, and poor in quality. Some plants, however, do not show noticeable dwarfing, and the growth may appear to be normal except for the presence of the spots.

Ringspot is often associated with mosaic in the field but either disease may occur independently. The symptoms are clearly not expressions of the same disease.

SYMPTOMS

The spots occur only on the leaves. They may be uniformly distributed and very numerous, or few and localized. The outline of the spot varies according to the location. They are circular when centered on inter-vein tissue (fig. 6), but when centered on the larger veins they are very irregular in outline. The infection follows the vein and its branches, and the outline of the spot often suggests that of a deeply-lobed leaf (figs. 3 and 4). The spots are bounded by definite broken lines of necrotic tissue which are

FIG. 2.—Advanced stage of ringspot on a leaf of dark tobacco. Rings are formed on the inter-vein tissue, and spots with irregular leaf-like outlines are formed on the veins. The margins are necrotic and blanched. Natural infection. Slightly enlarged.

blanched or brown in color (figs. 1 and 2). These necrotic margins form rings in the circular spots. Often the rings are doubled (figs. 5 and 6). The rings average about 5 to 8 mm. in diameter, but appreciable variation occurs. The center may be marked by a dot—although in many instances this is lacking—or by a small ring. The margins of the young spots appear as translucent lines in transmitted light, and there may be several zones of these with alternating zones of normal tissue, as in figure 4, A. The leaf tissue which borders the spots may be normal in appearance or it may be chlorotic, and in some varieties it may form a rather definite halo which is suggestive of the halo of the wildfire spot. The appearance of the tissue within the ring varies greatly according to the type of tobacco infected. In some varieties it may be only slightly chlorotic or normal green in color, but in some, which seem hypersensitive, it may become brown and necrotic throughout. The general appearance of the infections suggests the colony

type of growth of an organism or the diffusion of toxic substances from a center.

THE CAUSE OF RINGSPOT

No organism has been obtained consistently in isolations from ringspot and none of those isolated has proved pathogenic. Inoculum of crushed infected leaves, however, has produced infection repeatedly, and subsequent transfer has likewise produced infection. Four successive transfers were made in one instance. Infection is obtained by rubbing the crushed leaf on the trial leaf or by swabbing with a water infusion of affected leaves which have been ground in a mortar. Typical symptoms have been produced in both field and greenhouse. The discussion which follows relates to greenhouse work only.

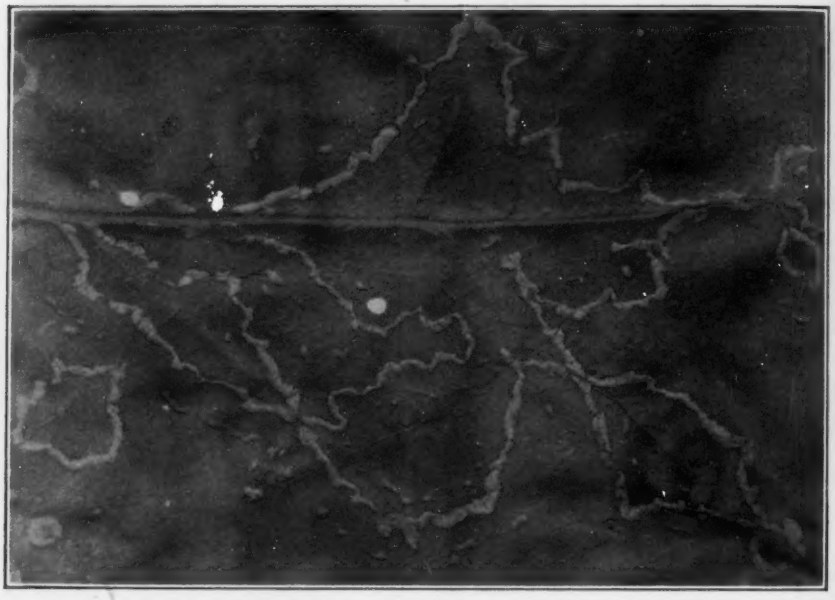

FIG. 3.—Ringspots with irregular leaf-like outlines which arise from vein infection. Natural infection. About twice natural size.

With plants of known susceptibility and with good inoculum one may secure infection in a high percentage of trials. Frequently all of the inoculated plants have become infected.

The incubation period has varied appreciably in different trials but these have covered a wide range of environmental conditions and the test material has been varied. In some cases we have noted the appearance of early symptoms four days after inoculation, and in others twelve or fourteen days have elapsed before definite symptoms appeared. The spots develop best

on young leaves or leaves of intermediate age, and little or no evidence of infection is obtained on leaves which have reached maturity. Young seedlings have been infected, and in one instance we have seen infection in the plant bed.

No extended study of the susceptibility of species and varieties has been made. Plants which were available of a number of species of *Nicotiana* and varieties of *N. tabacum* were tested on a limited scale. Only two or three plants of each type were tested as a rule, and failure to infect was not considered proof of resistance. Infection has been secured on five species of *Nicotiana, i.e., glutinosa, langsdorffii, paniculata, sylvestris,* and *tabacum.* The following varieties of *N. tabacum* were infected: *atropurpurea, auriculata, brasiliensis, calyciflora, colossea, gigantea, lacerata, latissima, macrophylla* and *microphylla.* The agronomic varieties, burley, Green's wildfire resistant, little Orinoco, Macedonian, and Maryland also proved susceptible.

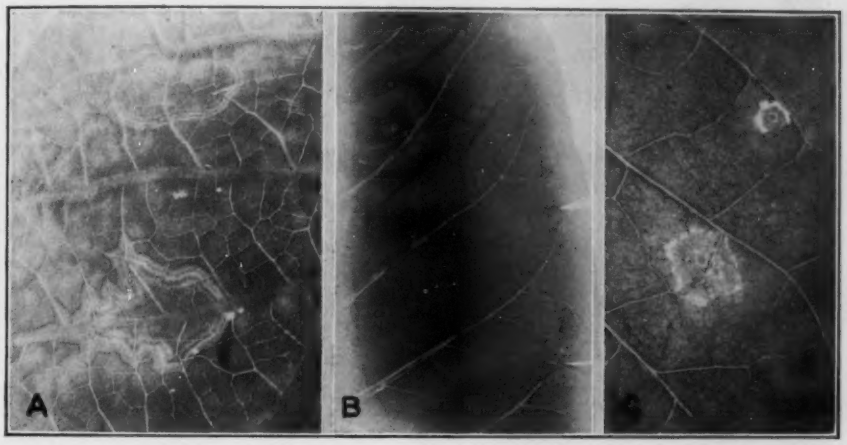

FIG. 4.—A. Ringspots in an early stage of development with margins of alternating zones of chlorotic and normal tissue. The extension of the spots in conformity with the vein pattern is well shown. Natural infection. Transmitted light. About 2×. B. In some varieties the margins of the spots appear as dark lines in transmitted light. Natural infection. Slightly reduced. C. Rings which developed from inoculation, as seen in reflected light. Photographed about 30 days after inoculation. Natural size.

A localized, rather than a systemic, infection is suggested by the appearance and occurrence of the spots since they are restricted to the parts of the leaf where the inoculum is applied. Other parts of the leaf remain normal in appearance throughout the life of the plant. There is evidence, however, that infection may become systemic in newly developed parts, especially in the axillary shoots. Ringspots have developed on new, uninoculated leaves of the main stem and suckers, and sometimes all leaves produced above the

point of inoculation have been infected. In one instance inoculum was injected with a syringe into the stem near the ground. The injection was made on October 7, and by November 16 a single ring appeared on one of the upper leaves. On November 30 two newly developed leaves of the top sucker showed infection. In another instance, infection was obtained with the crushed stem of a sucker from which the leaves had been stripped. Further evidence of systemic infection is shown in the behavior of a burley plant which was transplanted from the field to the greenhouse in late summer. With the death of the old infected leaves and the development of

FIG. 5.—Abundant ringspot infection of *Nicotiana tabacum* var. *lacerata* produced with inoculum from a variety of burley. The leaf also bears a few "blisters" of mosaic. Natural size.

new ones the symptoms disappeared, except for a faint mottling, but the leaf extract still proved infectious; and when the stalk was harvested and suckers appeared from the base, these also proved infectious.

As noted previously, ringspot and mosaic are frequently associated in the field and the two diseases evidently have similar potentialities. The incidence of mosaic is usually higher than that of ringspot; it seems to be more infectious or more readily transferred under field conditions. Ringspot is often restricted to a few plants, while mosaic, with an early start, may readily spread throughout the field by harvest. Similar differences in be-

havior are seen in the greenhouse. At one time, mosaic became established in one of the houses and spread so rapidly as to threaten the ringspot work. There has been little or no adventitious spread of ringspot; infection has appeared only on plants which have been inoculated. The same plant may bear both diseases, and inoculum from such plants usually produced both of them (fig. 5).

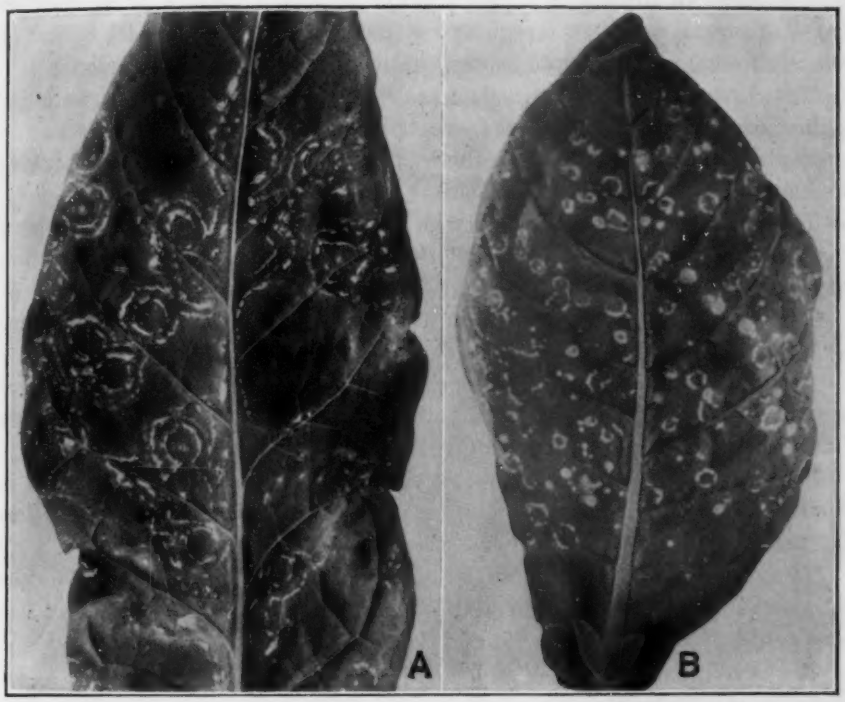

FIG. 6.—Ringspots which developed from inoculation. A. A leaf of a burley variety. Many of the rings are double. Small center rings or dots are seen in some. B. A sucker leaf of *Nicotiana tabacum* var. *microphylla* which developed some time after the inoculation of leaves of the main stem.

Such knowledge as we have would indicate that ringspot may be classed with the virus group of diseases. Its properties seem similar to those of the mosaics of tobacco and other plants, but it is also true that much remains to be learned. Our filtration studies have been too limited to warrant conclusions and we know but little of the factors which inhibit or enhance virulence.

It should be noted that Johnson (3) has produced a type of "ring-spot" from inoculations with juice of apparently healthy potatoes, and he sug-

gests that this disease may prove identical with ringspot of tobacco as it occurs in nature. His figure B, of plate 2, shows definite rings, but their identity with those of the disease which we have described seems questionable. Our inoculations of tobacco with juice of potato leaves have produced no symptoms of ringspot.

SUMMARY

The ringspot disease of tobacco is characterized by the occurrence on leaves of circular or very irregular lesions which are delimited by lines of necrotic tissue. The symptoms vary appreciably in different varieties.

The disease is infectious. It has been produced repeatedly with inoculum of the expressed juice of affected leaves. Transfer of infection is accomplished most readily when the leaves of trial plants are swabbed with the inoculum.

The symptoms may appear after an interval of four days, or longer, and they are at first restricted to inoculated parts of the leaves. The infection may become systemic later in newly developed shoots and leaves.

The disease has been produced in five species of *Nicotiana* and in a number of varieties of *N. tabacum*.

Attempts to culture a pathogen from diseased plants have been unsuccessful. This fact, together with other features of the disease, suggests that it should be classed with the virus group of diseases.

Ringspot occurs rather commonly in Virginia tobacco fields, but it is usually restricted to a low percentage of plants. High incidence of infection occurs rarely, and in such cases losses of consequence may follow.

Natural agencies or modes of transfer are unknown. The disease does not spread under greenhouse conditions, and, in our experience, there has been no adventitious occurrence of infection in the greenhouse.

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PRELIMINARY STUDIES ON WITCHES' BROOM OF STRAWBERRY

S. M. Zeller

INTRODUCTION

Early in the summer of 1925, Professor M. B. McKay, of the Oregon Experiment Station, discovered in Marion County, Oregon, an unusual disease of strawberry. At that time it was thought probable that this might be the same as the strawberry "yellows" which is so destructive to several strawberry varieties in the Central California Coast District and which has been recently described by Plakidas.[1] Further field study by the writer and a

Fig. 1.—Plant of the Marshall variety of strawberry affected with witches' broom. The larger healthy leaf at the upper left is a hold-over leaf, indicating that infection took place late the previous season. The baby plants at the right have the same symptoms. This plant was dug and photographed in April.

[1] Plakidas, A. G. Strawberry "yellows," a degeneration disease of the strawberry. Phytopath. **16**: 423–426. 1926.

comparison of symptoms of the two diseases by Plakidas has convinced us that the two sets of symptoms represent distinct diseases. The spindly habit of growth and multiplication of leaves has led the writer to call the new disease "witches' broom of strawberry."

The general performance of the disease and the suggestion by some growers that, although there is a tendency for it to spread, witches' broom can be kept to a very low percentage by means of roguing, have led us from the first tentatively to place the disease among the degeneration or virus diseases.

OCCURRENCE AND DISTRIBUTION

So far as the writer is aware this disease of strawberry has never been mentioned in literature.

Observations of witches' broom by members of the staff of the Oregon Experiment Station have been confined to the Willamette and Hood River Valleys of Oregon. It seemingly is of rare occurrence in this State. Several growers who produce plants for sale have been interested in the disease for a number of years. Its behavior taught them that baby or runner plants of diseased mother plants were always affected and the natural thing to do was to destroy such plants entirely. This fact and the fact that affected plants are worthless have led to roguing as a natural means of control and have consequently limited the distribution of affected plants. The several varieties which have been observed to be affected with witches' broom are Marshall, Nick Ohmer, Oregon, and Ettersburg No. 121. A strain of Marshall which goes under the names Improved Oregon and Improved Clarke has also been found with symptoms of this disease.

SYMPTOMS OF WITCHES' BROOM

The symptoms of the witches' broom of strawberry are expressed differently on different varieties of strawberry. These may be divided into two main types, those expressed by the diseased Marshall strawberry and those expressed by diseased plants of Ettersburg No. 121. Figure 1 illustrates the symptoms of the disease in the Marshall, although the photograph has not brought out the spindly character of the petioles. In this variety diseased plants have long, usually erect, stiff, spindly petioles upon which are borne leaflets which are much smaller than those of healthy plants. The leaves are usually light green, with a tendency toward olive green shades rather than bright green. The midveins of the leaflets arch downward. The lateral pinnate veins do not show this tendency so much but still enough so that the complete circle of three leaflets has the appearance of curving downward along the entire margin, in direct contrast to the upward cupping of the leaflets in strawberry yellows. There is a tendency for the stems of the

individual leaflets to be longer and for the midvein to be broader and lighter in color than in healthy plants. There is a noticeable turgidity of the leaflets and a crinkliness which is at least uncommon in healthy plants. The great number of leaves with long petioles gives the bushy appearance which suggested the name witches' broom. In the case of Marshall plants, flower stalks are very scarce and, when they do appear, are spindly and unfruitful; while the spindly flower stalks in Ettersburg No. 121 are very numerous and unfruitful.

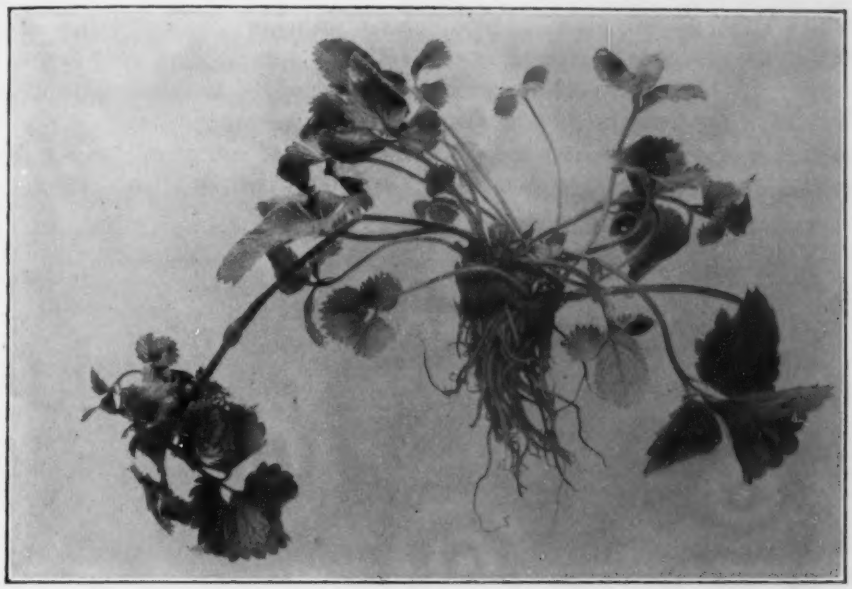

FIG. 2.—Marshall strawberry plant affected with witches' broom. Many of the leaves have been cut away to show the spindly character of the petioles and the small leaves.

The runners are very much shortened and the baby plants thus take root nearer the parent plants than is normal. The baby plants show the same symptoms as those described for the parent, but the former may show more advanced symptoms than the parent in cases where infection occurred late in the growing season. The root systems of diseased plants appear normal and well developed. Figure 2 illustrates the spindly character of the petioles of a Marshall plant, from which many of the leaves have been cut in order to show the individual leaves.

In the variety Ettersburg No. 121 the brooming or bushy character of the disease is much more pronounced than in other varieties, as is shown in figure 3. This variety naturally grows more bushy than other common varieties; thus this exaggeration of the disease symptoms is not surprising.

In affected Ettersburg plants the internodes of the runners are so extremely short that the baby plants take root right beside the parent crown. Figure 4 shows the parent plant with several baby plants rooted around it, two of them having been pulled aside to straighten and show the runner. The fact that baby plants with their numerous leaves are so closely crowded to the parent is perhaps one reason for the extreme brooming in diseased specimens of this variety. The leaves of the diseased Ettersburgs are not arched downward at the margins so decidedly as in the other varieties.

Plants which are too deeply planted sometimes make a peculiar growth which might be mistaken for symptoms of witches' broom. When baby plants are completely covered in cultivation, a spindly type of plant may result. To observe closely, however, in the case of the Marshall variety, the texture of the leaves of plants recovering from such unnaturally deep submergence in soil can be seen to be extremely delicate and pliable, in contrast to that of leaves of plants diseased by the witches' broom virus. The mar-

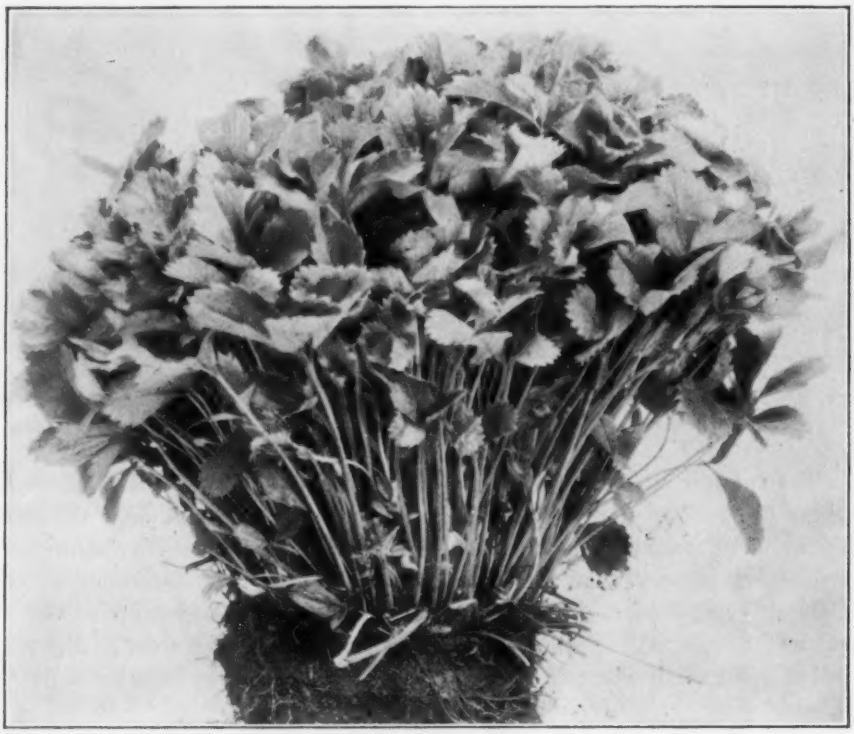

FIG. 3.—Plant of the Ettersburg No. 121 strawberry affected with witches' broom. This variety shows the "brooming" effect more than other varieties.

gins of the leaves of these deeply-planted specimen are definitely crenated but not particularly downward curved.

NATURE OF WITCHES' BROOM

Preliminary experimental work has led to the conclusion that witches' broom of strawberry is a virus disease which may be transmitted by insects. Transmission experiments were conducted during the season of 1926. Twenty-five healthy plants of the Marshall variety were enclosed in insect-proof cages, one plant in each cage. In addition, several diseased plants of Marshall and Ettersburg No. 121 were caged individually. For a transmission agency the strawberry leaf louse (*Myzus fragaefolii*) has been used.

The insect-proof cages for individual strawberry plants were constructed in the following manner. Half-inch-mesh chicken wire 36 inches wide was cut into strips 36 x 12 inches. Each strip was bent into a cylinder 12 inches high and approximately 12 inches in diameter so that the 12-inch edges could be stapled to a stake, 18 x 1½ x 1 inch, leaving the upper end of the stake flush with the wire mesh and 6 inches projecting below. The stake was inside the cylinder.

FIG. 4.—An Ettersburg No. 121 plant in which the baby plants have been pulled away from the parent to show the shortened internodes of the runners.

A very good grade of cotton sheeting (L L Caddo) was cut into 20-inch lengths and the selvage edges sewed together to form tubes. A cloth tube so made may be slipped snugly over the cylindrical wire frame until its lower edge can be hooked over the cut ends of the wires below. The 8 inches remaining above may be tied with a string. The cage is set over the plant and the 6-inch stake driven into the soil to hold the cage in place. A little soil placed around the base of the cage makes that portion satisfactorily insect-proof. An opening of any desirable size for making observations may be made where the upper end of the cloth tube is tied.

Aphis (leaf lice) obtained from healthy plants growing in a planting of Marshalls where no diseased plants were found were placed on some caged, diseased plants and on four of the caged healthy plants. After eight days, leaves harboring from two to three aphis were transferred from plants in these cages to healthy Marshall plants in insect-proof cages. From two to three aphis from diseased plants of Ettersburg No. 121 obtained from a commercial planting were transferred to each of several Marshall plants in cages. After about three to four weeks the new leaves appearing on some of the healthy Marshall plants to which aphis had been transferred from diseased Marshall or Ettersburg plants showed symptoms like those illustrated in figure 1. The results of the transmission experiments were as follows. Aphis transferred from the four healthy Marshall plants to as many healthy Marshall plants proved to be nonviruliferous, the plants remaining healthy six months after the insects were transferred to them. Nine out of fourteen Marshall plants have shown the symptoms of witches' broom in three to four weeks after aphis which had fed on diseased Marshall plants for 8 days were transferred to them, and 5 out of 7 Marshall plants showed the same symptoms within the same period after aphis which had fed for 8 days on diseased Ettersburg plants were transferred to them. After six months the same condition held, the symptoms having gradually become more and more apparent.

Although there was not a high percentage of transmission in either case, there is conclusive evidence that the disease is caused by a virus which may be transmitted by the aphid, *Myzus fragaefolii*. It is also apparent that the two groups of symptoms, those shown by the Marshall variety (Fig. 1) and those shown by the Ettersburg variety No. 121 (Fig. 3), are both expressions of the same virus disease, witches' broom. Transmission of the disease has not been attempted with any other insect to any extent. *Myzus fragaefolii* is therefore at present the only known agent or means by which the virus of witches' broom of strawberry can be transmitted. The disease has not been studied in its relation to climatic or other ecological factors.

SUMMARY

Witches' broom of strawberry is characterized by a dwarfing of the whole plant, spindliness of petioles and an arching downward of the margins of the leaflets, which are lighter in color than in normal plants. Runners are shortened, the baby plants with symptoms like those of the mother plant taking root near the parent. More broominess is exhibited by some varieties, like Ettersburg No. 121, than by other varieties.

Witches' broom has been found in western Oregon only, but may have wider distribution. Varieties have not been tested for resistance or susceptibility, but Marshall, Nick Ohmer, Oregon, and Ettersburg varieties have been found affected. Viruliferous leaf lice (*Myzus fragaefolii*) transmit the disease.

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PHYTOPATHOLOGICAL NOTES

A Wilt Disease of Alfalfa Caused by Fusarium sp. In September, 1926, H. L. Westover found a disease attacking alfalfa plants, about six months old, growing in his plots at the Government Experiment Station at West Point, Mississippi. The disease appeared similar to, but not quite typical of, the bacterial wilt caused by *Aplanobacter insidiosum* L. McC., recently described by Jones[1] and Jones and McCulloch.[2] Therefore, specimens were submitted to the writer for study. Westover stated in a letter that a large number of plants were dying and that many others had a sickly appearance. The affected plants appeared to be somewhat dwarfed and in some cases were dying from the top downward. The symptoms, however, were not very definite. When the bark was removed from a root or when cross sections of a root were examined macroscopically, a brown or reddish-brown discoloration of the xylem was evident. In early stages of the disease this discoloration appeared to be localized in the young xylem near the cambium. In some cases there was a more or less complete ring of discolored tissue, while in others only one or more bundles were thus affected. In advanced stages the entire woody cylinder was discolored. The discoloration could often be traced from the root into one or more shoots for a distance of three or four inches.

The writer has not had an opportunity to study the symptoms of this disease in the field, but the following points will help to distinguish it from the bacterial wilt, the disease with which it may possibly be confused. Although the color of the tissues affected with bacterial wilt varies, it is usually a shade of yellow or light-brown as contrasted with the darker brown or reddish-brown of those affected with Fusarium wilt. When viewed microscopically in cross section, the coloring matter in roots affected with bacterial wilt appears to be located largely within the lumina of the vessels, while in roots affected with Fusarium wilt the color is in the cell walls.

Isolations made by planting some of the discolored tissue on agar yielded a species of *Fusarium* in almost every instance. Plants of different ages growing in the greenhouse were inoculated with this *Fusarium* by four different methods. Infection resulted in a large percentage of the tests, and the fungus was reisolated from nearly every infected plant. The details of these experiments, together with others now under way, will be given in another paper. Under greenhouse conditions the disease first becomes evi-

[1] Jones, F. R. A new bacterial disease of alfalfa. Phytopath. 15: 243–244. 1925.

[2] Jones, F. R., and Lucia McCulloch. A bacterial wilt and root rot of alfalfa caused by *Aplanobacter insidiosum* L. McC. Jour. Agr. Res. 33: 493–521. 1926.

dent about two months after inoculation by the yellowing of the leaves and a gradual dwarfing and dying of the plants. Affected plants may wilt during the hottest part of the day and become turgid again later. The xylem of such plants always has more or less darkened areas as in naturally affected plants.

Nothing is known yet regarding the distribution of this disease, as it has never been seen except in the original collection. Although a detailed discussion of the pertinent literature will not be given at this time, a brief summary seems desirable. Several writers have reported a root rot, or wilt, or both, of alfalfa with which a species of *Fusarium* has been associated. In several cases the associated fungus is said to be *Fusarium roseum*. The *Fusarium* being studied by the writer is not that species. Most of the reports of Fusarium root diseases of alfalfa are so meager that they do not give very clear pictures of the true nature of these troubles. The most comprehensive descriptions of so-called Fusarium diseases are those by McCallum[3] and Cottam.[4] However, neither of these writers reproduced the disease experimentally. Arnaud[5] describes a disease of alfalfa in France as due to *Neocosmospora vasinfecta*.

Further study and field observations are necessary to determine whether the disease herein described is the same as any hitherto reported.

The writer would appreciate it very much if other workers would send him alfalfa plants suspected of having this disease, together with information regarding any damage it may be doing. Further studies are under way with a view to determining the identity of the causal fungus and other facts relative to its spread and control.—J. L. WEIMER, U. S. Department of Agriculture, in cooperation with the Kansas Agricultural Experiment Station.

Loose Kernel Smut on Feterita. Infections by feterita by *Sphacelotheca cruenta* (Kühn) Potter apparently have not been previously reported. Reed[6] inoculated seed of feterita with spores of this fungus, but no smutted heads resulted. The following observations were made by the writers at the U. S. Field Station, San Antonio, Texas, where seed of feterita (C. I. No. 182), which had been sprayed lightly with formaldehyde (one

[3] McCallum, W. B. Vegetable physiology and pathology. Ariz. Agr. Exp. Sta. Ann. Rept. **18**: 230–232. 1907.

———. Plant physiology and pathology. Ariz. Agr. Exp. Sta. Ann. Rept. **19**: 357–361. 1908.

[4] Cottam, W. P. A "dry rot" disease of alfalfa roots caused by a *Fusarium*. Phytopath. **11**: 383. 1921.

[5] Arnaud, G. Une nouvelle maladie de la luzerne. Prog. Agr. et Vit. (Éd. l'est-Centre) **54**: 517–519. 1910.

[6] Reed, George M. Varietal resistance and susceptibility of sorghums to *Sphacelotheca sorghi* (Link) Clinton and *Sphacelotheca cruenta* (Kühn) Potter. Mycologia **15**: 132–143. 1923.

pound to 10 gallons of water), was sown on March 24, 1926, in the sorghum varietal experiments. There was no evidence of smut when the plants were harvested on July 23. Because of rains following harvest, the feterita plants made a second growth and finally produced a second crop of heads. On September 28, when the seed of the second growth was in the dough stage, about 10 per cent of the heads were found to be infected with loose kernel smut. This indicated that the fungus had entered the plants, probably in the seedling stage, but that its development had been retarded so that the fungus did not reach the heads of the first crop. Hence the apparent immunity of feterita from loose smut infection may be merely the result of a retardation of the growth of the fungus within the host. This would be in the nature of escapement rather than immunity. The smut was identified as *Sphacelotheca cruenta* by Dr. W. H. Tisdale.—J. H. MARTIN, Office of Cereal Crops and Diseases, and G. T. RATLIFFE, Office of Western Irrigation Agriculture, Bureau of Plant Industry, U. S. Department of Agriculture.

Butt Rot in Diospyros virginiana caused by Polyporus spraguei. For several years a butt rot in living trees of the American persimmon (*Diospyros virginiana* L.) has been observed in southern Indiana. This rot is unusual because so far as the writer knows no heart rot of persimmon has ever been reported and because it was formerly thought that the peculiar black impregnation of the heart wood would probably inhibit the development of wood-destroying fungi. This belief was based on an experiment in which *Polystictus versicolor* failed to develop on a medium made with a decoction from the heart wood.

The butt rot was first observed in old basal scars in trees growing singly in fields. There was never any evidence of the presence of a fruiting fungus, and several examinations of the decayed wood failed to show mycelia that could be attributed to any of the usual wood-destroying fungi. On one of the writer's periodical visits to southern Indiana (Nov. 7, 1918), a large living field tree was found blown down. Growing directly from the decayed heart wood of the splintered butt was a small, poorly developed fructification of *Polyporus spraguei* B and C. The decay, naturally of a darker color in this wood than in any other, was in other characters typical of this fungus *viz.* carbonaceous. From the manner of the development of the fructification directly from the decayed wood, also from the fact that wood-destroying fungi of the first rank rarely find in wood already utilized by another fungus the nourishment necessary for their development, it is assumed that the decay in question was caused by *Polyporus spraguei.*

It is interesting to record that in the wet wood in the base of the stump nematodes were found. Since this time nematodes have been found in decayed wood of various trees and in rotted logs on the ground. Recently Dr.

N. A. Cobb has announced to the writer that he has also found nematodes in rotted wood. In light of the known enzymatic activity of wood-destroying fungi, the role of these organisms can only be a secondary one.

Indications are that *Polyporus spraguei* is a fairly common wound fungus. The writer has called attention to it as causing a butt rot in *Quercus* and *Castanea*.[1] The fungus is usually found on dead wood of *Quercus*, *Castanea*, *Fagus*, and rarely on *Fraxinus*. The fungus apparently prefers the hard, firm woods.

Polyporus spraguei is not supposed to occur in Europe. A form on chestnut in France has been described by Bourdot and Galzin[2] under the name *Polyporus castaneae*. The type of the species in its gross characters is indistinguishable from the American plant. The minute characters are as follows: Spores ovoid to globose hyaline, uniguttulate apiculate, 5.5–7 × 4.5–6 μ, tramal hyphae homogenous 2–4 μ, context hyphae 2–4 μ rarely 5–6 μ. The microscopical characters of the type of *Polyporus spraguei* (Sprague 822, 974, Herb. Curtis 5700 and 5718 collected by Dr. Murray in Massachusetts) are—spores ovoid to subglobose hyaline, uniguttulate, apiculate average 5–6.5 × 4–5.5 μ, tramal hyphae homogenous 2–3.1 μ, context hyphae 2–4.5 μ. The writer collected the European fungus in France in 1910 on *Quercus*. The decay was found to be the same as that caused by the American fungus in *Quercus*. It appears that the two forms should not be held distinct.—JAMES R. WEIR, United States Department of Agriculture, Washington, D. C.

[1] Weir, James R. *Polyporus spraguei* Berk., cause of heart rot. Phytopath. 13: 288. 1913.

[2] Bourdot, H., and A. Galzin. Hymenomycetes de France II. Pores. Bull. Myc. Soc. Fr. 41: 105. 1925.

BOOK REVIEW

Manual of Plant Diseases. By F. D. Heald. Edition I, 891 pages, 272 figures. 1926. McGraw-Hill Book Co., Inc.

Plant pathologists of America have for years felt the need of a text adequately covering the fundamentals of their field. "Fungous Diseases of Plants" by Duggar, issued in 1909, has for some years been inadequate owing to the rapid advances which have been made in the field of pathology and mycology. Manuals of diseases of special crop groups have been published. They, however, have not satisfied the requirements for a college text presenting the fundamentals of the subject. The teaching pathologist will welcome the appearance of Heald's "Manual of Plant Diseases," which is a book for the class room, based on lectures of the author prepared for his classes.

The book is divided into four sections, the first devoted to an introduction which includes a historical sketch of the science and its development and a second chapter on symptoms of disease in plants.

The second section is devoted to a consideration of non-parasitic diseases. There are nine chapters in this section, covering some 170 pages. The chapters are devoted to such subjects as "Diseases due to—deficiencies in food materials in the soil;—excesses of soluble salts in the soil;—unfavorable water relations;—improper air relations;—high temperatures;—low temperatures;—unfavorable light relations;—manufacturing or industrial processes; and—control practices." This is a very welcome feature as this phase of plant diseases needs to be brought to the attention of our students more than has been the custom in the past. Diseases due to environmental and soil conditions and to parasites dovetail so frequently that the student unfamiliar with the first is blind to an important phase of his work. Developing this phase of the subject before the parasitic diseases is a good arrangement, as it provides a good backing for the latter.

The third section, consisting of one chapter covering 55 pages, is devoted to "Virus and Related Diseases" and embodies a general discussion of diseases of this type with detailed consideration of Peach yellows, Little peach, Potato leaf-roll and Potato mosaic. Other diseases of this type are briefly described or listed with reference to important contributions.

The main, or fourth, section, occupying about two-thirds of the book, takes up "Parasitic Diseases" and consists of 16 chapters. The last two chapters of this section are devoted to the consideration of parasitic seed plants and Nematodes, and the diseases they cause. The major portions of the section are devoted to diseases caused by bacteria and fungi. Some 40 diseases caused by members of these two groups are given major consideration, and are grouped according to the mycological position of the pathogenes. In this section the author gives considerable attention to the morphology of the bacteria and fungi. The figures for this phase of the study are especially clear, and will be found helpful to those studying morphology. The discussion of the diseases is developed around such paragraph headings as History and Distribution, Symptoms and Effects, Etiology, Predisposing Factors, Host Relations, and Control. (One misses a detailed discussion of the vascular wilts.)

The discussions are clear and unusually free from technical language. The photographs are well chosen and the majority well reproduced; a few do not show the detail they should.

In the writer's opinion Doctor Heald has prepared a good and acceptable book. Some of the matter presented, however, might wisely have been condensed to give space for a discussion of the principles of parasitism, resistance and susceptibility, inoculation, infection, dissemination, the relation of environment (soil and air temperature, humidity and soil reaction) to infection and development of infectious diseases, the fundamental principles of control. Much of this is presented in the book in the consideration of specific diseases but not in a connected form which would be of value and help to the student and the instructor.

The mechanical construction of the book is good; the type is clear and large and the book as a whole is that of McGraw-Hill standard.—A. B. MASSEY, Virginia Polytechnic Institute.

REPORT OF THE EIGHTEENTH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The eighteenth annual meeting of the Society was held at Philadelphia, December 28–31, 1926, in conjunction with the American Association for the Advancement of Science. The headquarters were at the Hotel Normandie and about 200 members were in attendance.

The program contained 61 papers, 9 in general session, 3 in joint session with Section G, 12 in joint session with the mycological section of the Botanical Society of America, and the remainder grouped in sections under cereal diseases (7), fruit diseases (8), vegetable diseases (15), and fungicides (7). Abstracts of papers were distributed at the meeting and were published in the January number of the 1927 volume of PHYTOPATHOLOGY.

A popular account of the meeting by W. A. McCubbin and H. W. Thurston has been printed in the report of the Permanent Secretary of the American Association (Science 65: 106–107. 1927).

The papers presented at the joint session with Section G were: *Leaf Structure and Wound Response*, by R. B. Wylie; *The Accumulation of Electrolytes*, by W. J. V. Osterhout, and *Vigor of the Host as a Factor in the Development of Disease*, by F. D. Fromme.

A plant disease survey round-table session was introduced for the first time this year. Reports were made on disease conditions in the various states, and specimens and photographs of new or otherwise interesting diseases were exhibited. The meeting was held at the hotel headquarters and was attended by about 80 members.

The conference on extension work in plant pathology devoted its afternoon session to a discussion of the wheat bunt situation, the subject of the copper-carbonate seed treatment being considered in detail.

A very instructive and pleasurable feature of the meeting was the Friday excursion to Wilmington and vicinity as guests of the E. I. du Pont de Nemours & Company. About 100 persons took the trip, which was by boat to the company's plant at Deep Water, New Jersey, and to Wilmington. Busses then conveyed the party to the Wilmington Country Club for lunch and later to the wonderful conservatory of Mr. P. S. du Pont at Kennett Square, Pennsylvania. At Deep Water the buildings and equipment of the Jackson laboratories were inspected, and the experimental work, as well as a motion picture on seed and soil disinfectants, were seen.

The phytopathologists' dinner at the Hotel Normandie was attended by 194 persons. The dinner program was especially arranged in honor of Dr. Erwin F. Smith, who has contributed so much to our science during the 40 years of his service in the Department of Agriculture. After appropriate remarks, the president, I. E. Melhus, introduced Dr. L. R. Jones, who spoke on Doctor Smith's service to plant pathology. He was followed by Dr. W. H. Welch, of Johns Hopkins University, who spoke on Doctor Smith's contributions to human and animal pathology. Dr. F. V. Rand, chairman of the committee on arrangements, then presented Doctor Smith, in the name of the Society, with a beautiful leather-covered brochure in which were engrossed the abstracts of speeches that had just been made, followed by the autographs of the members present. Other features of the dinner program were singing led by Donald Porter, a report on an official seal for the Society by H. B. Humphrey, and a report by Donald Reddick, secretary of the plant pathology section of the International Plant Congress at Ithaca.

OFFICERS AND REPRESENTATIVES

The following officers were chosen, the first five being elected by the Society under the new method of balloting, and the others selected by the council and approved by the Society.

President, M. F. Barrus, New York State College of Agriculture, Ithaca, N. Y.

Vice-President, H. P. Barss, Oregon Agricultural College, Corvallis, Ore.

Councilor (two years), C. L. Shear, Bureau of Plant Industry, Washington, D. C.

Representatives on Board of Control of Botanical Abstracts, F. D. Fromme, Virginia Polytechnic Institute, Blacksburg, Va. (four years); E. C. Stakman, University of Minnesota, St. Paul, Minn. (two years).

Associate Editors of Phytopathology (three years), Freeman Weiss, Bureau of Plant Industry, Washington, D. C., to complete the unexpired term of W. H. Tisdale, resigned; Leslie Coleman, University of Toronto, Toronto, Canada, to succeed B. T. Dickson; M. N. Levine, University of Minnesota, St. Paul, Minn., to succeed A. W. Henry; F. J. Schneiderhan, Virginia Polytechnic Institute, Blacksburg, Va., to succeed C. A. Ludwig.

Business Manager (one year), R. J. Haskell, Bureau of Plant Industry, Washington, D. C.

Advertising Manager (one year), J. F. Adams, Agricultural Experiment Station, Newark, Del.

Representatives on the Council for the American Association for the Advancement of Science (one year), G. P. Clinton, Agricultural Experiment Station, New Haven, Conn., and Donald Reddick, New York State College of Agriculture, Ithaca, N. Y.

Representative on Committee on American Type Culture Collection (three years), C. L. Shear, Bureau of Plant Industry, Washington, D. C.

Members of the Advisory Board (three years), E. L. Nixon, Pennsylvania State College, State College, Pa., to succeed N. J. Giddings as commissioner for the Northeast; J. G. Dickson, University of Wisconsin, Madison, Wis., to succeed M. W. Gardner as commissioner for the Mid-West.

Member of the Board of Governors of the Crop Protection Institute (three years), H. W. Anderson, University of Illinois, Urbana, Ill., to succeed M. F. Barrus. The other two members of the board are N. J. Giddings and I. E. Melhus.

Representative on the Division of Biology and Agriculture of the National Research Council (one year), F. D. Fromme, Virginia Polytechnic Institute, Blacksburg, Va.

The following temporary committees were appointed by the President to serve throughout the meetings: *Resolutions Committee*, L. M. Massey, H. A. Edson, and L. E. Melchers; *Auditing Committee*, G. K. K. Link, E. S. Schultz, and J. B. Kendrick; *Committee on Publicity*, W. A. McCubbin and H. W. Thurston, Jr.; *Committee on Dinner Tickets*, R. S. Kirby and W. A. Archer; *Committee on Meeting Rooms*, I. E. Vogel.

REPORT OF THE SECRETARY-TREASURER, 1926

At the close of the Kansas City meeting the membership totaled 672. During the year 5 were reinstated, and a loss of 27 was sustained—20 by suspension for non-payment of dues, 4 by resignation, and 3 by death, making a total membership of 650 at the close of 1926. Of these, 115 were life members and 535 regular members. At Philadelphia 66 new members were elected, thus bringing the total up to 716. Of the new members 12 came from New York, 6 each from Iowa and Japan, 5 from Wisconsin, 4 each from California and Florida, 3 each from Canada and Minnesota, 2 each from Indiana, Illinois, England and China, and 1 each from 15 scattered states and countries.

STATEMENT OF ACCOUNTS FOR 1926, AS OF DECEMBER 20, 1926

Receipts:

Balance from 1925			$1,992.41
Annual dues: 1923	$ 4.00		
1924	4.00		
1925	49.80		
1926	987.30		
1927	1,594.98		
1928	5.00		
1929	4.00		
1930	4.00		
		2,653.08	
Excess dues		6.25	
Interest on checking account		47.43	
Cash returned by secretary-treasurer on expenses		51.59	
Dues in Phys. Section received with annual dues		1.00	
			$4,751.76

Expenditures:

Member subscriptions transferred to Phytopathology	$1,777.00	
Secretarial work	96.00	
Postage stamps and registry	37.17	
Telegrams	1.60	
Printing (preliminary announcements, dinner tickets, lists of members, letterheads, nomination blanks, ballots, envelopes)	78.63	
Expense of motion picture apparatus at Kansas City meeting	17.50	
Miscellaneous expenses of Phytopathological dinner	15.00	
Check returned by bank	4.00	
Expenses of Committee on International Botanical Congress	296.06	
Sales received with dues transferred to Phytopathology	7.50	
Purchase of stamped envelopes, printed	79.26	
Donations to European subscribers transferred to Phytopathology	60.98	
Excess dues refunded	1.00	
Dues in Phys. Section paid	1.00	
Advanced to Secretary-Treasurer for expenses at Kansas City meeting	150.00	
		2,622.70
Balance		2,129.06
Outstanding check		1.00
		$2,130.06
Amount of above receipts credited to 1927–1930	$1,607.98	
Amount due sinking fund	294.00	
Member subscriptions due Phytopathology	31.00	
		1,932.98
Actual balance for 1926		$ 197.08

REPORT OF THE BUSINESS MANAGER OF PHYTOPATHOLOGY FOR 1926

PHYTOPATHOLOGY continues to be in good condition financially even though the bank balance at the close of the year, $1,103.84, is less than that of last year by $1,167.55. This is largely due to the publication of a larger volume of Phytopathology this year. On account of the increased number of pages and illustrations, it cost some $1,400 more to manufacture it in 1926 than it did in 1925.

The number of subscribers in good standing on the list at the close of the year is 419, of which 254 are foreign and 165 domestic. This is an increase of 12 over the number on the list a year ago. The present edition of PHYTOPATHOLOGY is 1,475 copies, of which 1,069 are being mailed out.

Advertising receipts increased from $1,110.78 in 1925 to about $1,434 in 1926. Credit is due the Advertising Manager for steady and persistent work in securing new advertisements and retaining old ones.

The sinking fund has now passed the $5,000 mark, and is $5,044 to be exact.

STATEMENT OF ACCOUNTS FOR 1926, AS OF DECEMBER 20, 1926

Receipts:

Balance from 1925			$2,271.39
Subscriptions ($424.19 for 1927 and 1928)			1,885.88
Sales			612.77
Advertising: 1925	$ 147.80		
1926	1,273.84		
1927	35.30		
			$1,456.94
Interest on sinking fund and investment			368.75
Member subscriptions for 1926			1,777.00
Donations to European subscribers for 1924 and 1925			60.98
		8,433.71	$8,433.71

Expenditures:

Manufacturing Phytopathology:			
Vol. XV, No. 12	$ 535.39		
Vol. XV, Index	136.14		
		$ 671.53	
Vol. XVI, No. 1	530.44		
Vol. XVI, No. 2	445.89		
Vol. XVI, No. 3	521.02		
Vol. XVI, No. 4	446.52		
Vol. XVI, No. 5	363.28		
Vol. XVI, No. 6	366.41		
Vol. XVI, No. 7	356.03		
Vol. XVI, No. 8	498.79		
Vol. XVI, No. 9	547.04		
Vol. XVI, No. 10	566.65		
Vol. XVI, No. 11	833.37		
Engravings for Vol. XVI	840.33		
		6,315.77	
			6,987.30

	$6,987.30	
Printing Phytopathological Abstracts	37.90	
Expenses of Editor-in-Chief (letterheads, postal cards)	18.79	
Expenses of Advertising Manager (postage and stenography)	30.35	
Postage, mailing back volumes from College Park	17.76	
Secretarial work	202.50	
Miscellaneous expenses (graphs, photograph)	7.00	
Duplicate subscriptions refunded	13.27	
Subscriptions to other journals sent by error refunded	5.00	
Postage, Business Manager	10.00	
	$7,329.87	$7,329.87
Balance		$1,103.84
Outstanding checks		914.98
		$2,018.82

Assets:

Cash in bank (balance shown in statement of account)	$2,018.82
First mortgage (surplus)	1,000.00
Sinking fund (invested)	4,750.00
Amount due sinking fund (now in Society's account)	462.00
Amount due from subscriptions	467.75
Amount due from advertising	121.30
Amount due from sales made	61.40
Member subscriptions due to date	672.00
Cash and checks on hand to be deposited	164.40
	$ 9,717.67
Estimated value of back numbers of PHYTOPATHOLOGY for sale	13,500.00
Total assets	$23,217.67

Liabilities:

None.

REPORT OF THE EDITOR-IN-CHIEF OF PHYTOPATHOLOGY

Volume 16 of PHYTOPATHOLOGY contains 1,012 pages, comprising 79 articles, 21 notes, 5 reports and 4 book reviews; 55 plates and 124 text figures. About 100 manuscripts were submitted. Of these, 19 were returned for revision and 11 rejected.

There were two hundred pages more in volume 16 than in volume 15. Fewer manuscripts were handled. On the average, the papers have been longer. The number returned for revision this year, compared with 35 during 1925, indicates that the manuscripts were more carefully prepared than last year. However, perfection has not yet been attained. Authors should consider more carefully methods of presentation, such as subdivision of the article into sections, methods of citing literature, table headings, and legends for illustrations. All authors should have some one with good critical sense read their manuscripts before they are submitted for publication.

The average length of time required to get papers into print, on the basis of the number published during 1926, has been five months from the date of submittal to the

month of issue of the Journal. It is doubtful that this time can be shortened very much. The editor does not always find it possible to read a paper on the same day on which it is received. Manuscripts often must be sent to other members of the Editorial Board and to other people for criticism and advice, then they must be marked for the printer, authors must be consulted by mail, and considerable time is usually consumed in the printery. The sending back and forth of proofs and all the other necessary details usually require at least four months.

The tendency of many authors to ignore previous work along the same line is becoming very pronounced. While it ought not to be necessary to go back to Theophrastus in the literature review of every paper, it certainly borders on the unethical to let an article carry the imputation that it contains the results of first work done along that line. There is, of course, a mass of literature pertaining to many subjects. However, it should be possible to refer to at least some of the more important of the previously published papers. A solution of this problem can not be reached by mathematical formulae. It is respectfully urged, however, that all contributors say the Golden Rule over to themselves several times and then think about it before they begin their literature reviews.

Prolixity is a fault in many manuscripts. Papers should be just as concise as possible: all irrelevant and unimportant matter should be eliminated. Most manuscripts could be reduced 25 per cent without decreasing their value. In fact, the value of many of them would be increased. More good material can be published if every one tells his story in as few words as possible.

Illustrations must be improved. Many of the prints submitted could not possibly show any details after reproduction. Authors should give thought, also, to the arrangement of the figures in plates. They should be neatly and clearly labeled, and the legends should be concise but clear. Illustrations should add something to the value of the article—many of them do not.

While there has been considerable improvement in manuscripts received this year, far greater improvement can and should be made.

REPORT OF THE ADVERTISING MANAGER

The advertising returns have shown a reasonable increase for the year 1926. The total number of advertisements appearing in the 12 issues is 156 or an increase of 24 per cent. This total of advertisements was distributed as follows: 49 full pages; 67 half pages; 34 one-fourth pages; and 6 one-eighth pages, making a total of 91¾ pages of advertising or 22½ pages over 1925, representing a 24 per cent increase.

We have experienced better cooperation this past year with commercial companies manufacturing spray materials. However, it has been difficult to develop contact with those concerns manufacturing spray and laboratory equipment. It would materially assist to increase our advertising returns if members would cooperate and assume a little initiative in developing contact through representatives of companies with whom they are acquainted which should be among our list of advertisers. Only three members this past year assisted in securing our advertising. It is our experience that personal appeal and contact only is productive of results. The wide territory that our membership represents should certainly assist in broadening the possibilities of PHYTOPATHOLOGY as a practical and economical publication in which to advertise.

PHYTOPATHOLOGICAL CLASSICS

The editors of "Phytopathological Classics" reported through H. H. Whetzel that the first number, a translation of the paper of Fabricius on "Attempt at a Dissertation

on the Diseases of Plants,'' is now on sale. It may be secured from the Business Manager of PHYTOPATHOLOGY as long as the supply lasts, at 40 cents a copy. Exactly 100 copies were sold during the meetings.

REPORT OF THE ADVISORY BOARD

The personnel of the board for 1926 is as follows: N. J. Giddings, chairman, representing the Northeast; F. C. Meier, secretary, representing the U. S. Department of Agriculture; M. W. Gardner, representing the Midwest; B. B. Higgins, representing the South; S. M. Zeller, representing the West; J. E. Howitt, representing Canada; and F. D. Fromme and M. F. Barrus, representatives at large. The Council appointed J. G. Dickson to succeed M. W. Gardner, and E. L. Nixon to succeed N. J. Giddings. At a meeting of the Advisory Board, F. D. Fromme was elected chairman for 1927.

Summer Meetings. A summer meeting of the Society was held on Saturday, August 21, at Ithaca, New York, at the time of the meeting of the International Congress of Plant Sciences. It rained hard all day so that only a few persons went on the trip, which included a visit to the pathological greenhouses at the New York State College of Agriculture and to the vegetable gardens and the virus disease plantation on the college farm.

At the annual meeting of the board it was decided to accept the invitation from Ohio to hold the summer conference in that state. Dr. H. C. Young, of the Ohio Agricultural Experiment Station, was appointed chairman on arrangements.

The Arthur Rust Project. The rust book is nearly completed, only one chapter remaining to be written. The funds for the completion of the project appear to be sufficient.

Investigations Conducted Through the Crop Protection Institute. (From a report submitted by W. C. O'Kane, chairman of the Board of Governors.) Activities of the Crop Protection Institute in 1926 have continued along substantially the same lines as those followed in the last four or five years. The institute is administering various investigational projects, as noted below, and is publishing the results where conditions warrant publication. The scope of its work is gradually increasing, as more and more industrial organizations entrust it with funds for the prosecution of research.

Direction of the Institute's activities rests with the Board of Governors, three of whom are named by the American Association of Economic Entomologists, three by the American Phytopathological Society, two by the Association of Agricultural Chemists, and one by the National Research Council. The members of the Board for the year just closed have been as follows: Prof. P. J. Parrott, Geneva, N. Y.; Dr. N. J. Giddings, Morgantown, W. Va.; Dr. I. E. Melhus, Ames, Ia.; Prof. W. C. O'Kane, Durham, N. H.; Dr. M. F. Barrus, Ithaca, N. Y.; Mr. W. P. Flint, Urbana, Ill.; Mr. Paul Moore, Washington, D. C.; Dr. B. L. Hartwell, Kingston, R. I.; Dr. H. J. Patterson, College Park, Md. The officers of the board for the past year have been W. C. O'Kane, chairman, Durham, N. H., and Paul Moore, secretary, Washington, D. C.

Active projects on hand are as follows (only projects of especial interest to plant pathologists are reported below):

The copper investigations, which were begun in April, 1925, with funds supplied by copper refiners, have been continued with headquarters at the Boyce-Thompson Institute at Yonkers, N. Y., with Dr. Frank Wilcoxson as investigator. Some interesting new copper compounds have been worked out which promise to be of value as fungicides and which will be tested in the field the coming season.

The crown gall studies supported by the American Association of Nurserymen and an independent committee of nurserymen, with additional funds supplied by the Iowa

State College and the University of Wisconsin, have continued with headquarters at Madison and Ames. The investigators employed have been: Dr. A. J. Riker, Mr. L. W. Boyle, Dr. J. H. Muncie, and Mr. M. K. Patel. In the course of the present year an appropriation assigned to the Department of Agriculture became available for certain phases of this work and the organization of the work was rearranged accordingly. The American Association of Nurserymen again voted funds which the Institute is administering.

The study of seed-borne parasites, supported by funds supplied by the Bayer Company, Inc., with Dr. C. R. Orton in charge, continued through the year, with headquarters at the Boyce-Thompson Institute.

A renewal of contract was made with the Miner Laboratories of Chicago, on behalf of the Quaker Oats Company, for a study of furfuramid and related compounds. Necessary funds have been made available and the work will start early in the coming calendar year, with headquarters at Ames, Iowa.

Publications of the year include the following: Bulletin 8, "Colloidal Sulphur: Preparation and Toxicity"; Bulletin 9, "Suggestions on the Preparation of Apple Grafts"; Bulletin 10, "The Effectiveness of Various Fungicides in Controlling the Covered Smuts of Small Grains."

REPORTS OF OTHER COMMITTEES AND REPRESENTATIVES

Representative on American Type Culture Collection. C. L. Shear presented the following report:

"The culture collection which is in charge of Doctor Weaver, of the John McCormick Institute in Chicago, under the direction of a committee composed of representatives from the bacteriologists, plant pathologists and other societies, has shown satisfactory development during the past year. The collection now includes pure cultures of about 1,200 different organisms, about 700 bacteria, 175 yeasts, 68 Actinomyces and 250 other fungi. About 2,715 cultures have been distributed during the year, and receipts from the sale of cultures have amounted to $2,332.75. A printed catalogue of the available cultures is now in process of publication, and will soon be available for distribution. It is hoped that all who are interested in pure cultures of microorganisms will avail themselves of this opportunity to secure them. More funds are needed for the development of the project. The Association of American Bacteriologists is contributing $400 per annum, and it is suggested that, if the American Phytopathological Society has any funds which might be available for this purpose, a contribution would be very helpful in carrying on the work. It is also suggested that all persons having pure cultures of new or interesting microorganisms, especially fungi, send samples of such cultures in order that they may be added to the collection and made available to other investigators."

Committee on Public Information Service. W. A. McCubbin and F. C. Meier submitted the following report which was adopted:

"A plan for getting before the public, through the press, magazines, etc., information regarding the work and results of plant pathologists over the whole country was presented to the Society at its annual meeting in Kansas City and there adopted. Under this plan there is called for a committee to direct the policy of this work; an editor and assistant editor, to be appointed by the Council upon recommendation of committee; a series of collaborators, as far as possible representing each state, whose function will be to send in all material which could be used for publication from their states; and a staff of writers who would prepare suitable press articles from the material submitted.

"The editorial staff will act as a central point of contact for the collaborators, the writers, and the press outlets, and since this staff is responsible to the Society through

the council there is thus provided direct control of the whole program and policy by the Society itself. The committee chosen consisted of: W. A. McCubbin, G. R. Lyman, and F. C. Meier; and the editorial staff nominated by them and approved by the council: editor, W. A. McCubbin, and associate editor, F. D. Fromme. The committee arranged for the services of two men who have had considerable experience in writing for the press and magazines and who, at the same time, are members of the Society so that their viewpoint and the accuracy of their statements could be relied upon. Two other men of similar training and experience have been located to be called upon if need arose. By correspondence and personal visits of the staff, an assured outlet for all suitably prepared material was provided for through Science Service.

"The committee further prepared a list of men in the various states who would probably be most satisfactory as collaborators, and these were canvassed by circular as to their willingness to undertake this part of the work. To the 48 letters thus sent out, 29 replies were received; 27 agreed to assist and two were not in sympathy with the movement. The general tone of the replies was distinctly favorable to the scheme and expressed a willingness to help it. The committee then sent out a sheet for the guidance of the state collaborators, indicating the general program, outlining the method of procedure that was to be followed, and giving in some detail the type of material that would be acceptable from the collaborators together with the additional information that would be useful in write-up work.

"The above report indicates the steps that have been taken to date to put this plan into effect. This committee urges on the members of the Society as well as on individual collaborators to give this plan earnest support, especially during the initial period. Your committee feels assured that when the scheme has become firmly established the obvious benefits that will come to the author, the State, and the institution from widespread, accurate and sympathetic publicity will create a momentum which will render its success certain as the years go on."

Resolutions Committee. The chairman, L. M. Massey, presented the following resolution which was unanimously adopted:

Resolved: The American Phytopathological Society wishes to express its appreciation to the University of Pennsylvania, especially to the Committee on Local Arrangements, for the excellence of the arrangements provided for our meetings; and to the citizens of Philadelphia for their kindness and hospitality during our visit.

Auditing Committee. The Auditing Committee reported through its chairman, G. K. K. Link, as follows:

The Committee on Audits has examined the books of the Secretary-Treasurer of the American Phytopathological Society. We find the assets, liabilities, receipts, expenditures, and balance as reported by the Secretary-Treasurer to be correct. The committee takes this occasion to compliment the Secretary-Treasurer for the condition of the books.

Permanent Committee on Necrology. The formal report of this committee concerning the three members of the Society who died during 1926, George Richard Lyman, Richard Chambers Walton, and Harold Wakefield Fitch, will be found at the end of this record. It was the last order of business and the ceremony in connection with the making of the report was impressively conducted by Doctor Jones for the committee, which consists of Haven Metcalf, G. P. Clinton, and L. R. Jones.

ACTION OF THE COUNCIL

In addition to making the appointments of officers mentioned at the beginning of this report, the Council considered a project of mycological surveys in foreign countries proposed by J. R. Weir and submitted to the Society by the National Research Council

for an opinion. The following motion with regard to it was passed by the Council and approved by the Society:

"It is believed that information of the type to be secured by mycological surveys will be extremely valuable. The general principle of such surveys in foreign countries is good. The Council has not had time to consider the plan proposed for conducting these surveys in sufficient detail to express an opinion on this part of the project."

The Council also passed a motion—

"That the American Phytopathological Society recommend to the Council of the American Association for the Advancement of Science that they invite the Southern Association of Agricultural Workers to meet with them next year at Nashville."

It was voted also to appropriate a sum sufficient to cover the cost of the testimonial gift presented to the guest of honor on the occasion of the annual dinner.

MISCELLANEOUS BUSINESS

Dr. L. R. Jones discussed the question of securing disease-free seed and made the following motion, which was passed:

Moved: That the American Phytopathological Society recognizes the need of better development and increased use of methods for encouraging plant improvement, especially with respect to the development or discovery of disease-resistant strains through breeding or through collection and study of varieties already in existence, and with respect to the production of disease-free seeds whether by disinfection, field inspection, certification or other means. Said Society hereby authorizes its President to appoint a special committee to cooperate to this end with representatives of the American Seed Trade Association, the National Canners' Association, and any other representative organizations interested in the matter.

The President appointed on this Committee on Plant Development, L. R. Jones, chairman, M. F. Barrus and M. W. Gardner.

The reports of officers and committees as given in the preceding pages of this report were adopted, as was also the Secretary's report of the last annual meeting (Phytopath. **16**: 647–663. 1926).

At the annual dinner, the vice-president, H. B. Humphrey, presented a report for the Committee on an Official Seal for the Society. Several designs that had been submitted were thrown on the screen, and an appeal was made for more suggestions and sketches from the members. It is hoped that the members will heartily cooperate in this matter with the result that a dignified and appropriate seal may be selected at the next meeting.

It was voted, on a motion by A. G. Johnson, that an expression of appreciation be sent to the Graduate School of the University of Minnesota for their financial assistance to PHYTOPATHOLOGY during the past two years.

The next regular meeting of the Society will be held at Nashville, Tennessee, December 28, 29 and 30, 1927.

R. J. HASKELL, *Secretary.*

IN MEMORIAM

GEORGE RICHARD LYMAN, 1871–1926

George Richard Lyman was graduated from Beloit in 1894 and from Harvard in 1897. He also received from Harvard the degrees of A.M. in 1899 and Ph.D. in 1906.

From 1894 to 1896 he was Superintendent of Schools at Amboy, Illinois. During his stay at Harvard he held the Austin Teaching Fellowship in Cryptogamic Botany, and during 1900–1901 he was also Instructor in Botany at Radcliffe. In 1901–1903 he was Instructor and during 1904–1915 Assistant Professor of Biology (Botany) at Dartmouth. From 1906 to 1914 his summers were spent at Woods Hole on the staff of the Marine Biological Laboratory. During the academic year 1912–1913 he was Lecturer in Cryptogamic Botany at Harvard, taking over temporarily the teaching of Dr. Roland Thaxter. In 1915 he joined the Office of Forest Pathology at Washington, but within a few months was transferred to the Federal Horticultural Board. In 1917 he was appointed Pathologist in Charge of the newly organized Plant Disease Survey. In January, 1923, he was made Dean of the College of Agriculture in the University of West Virginia, which position he held at the time of his death.

Dean Lyman was Vice-President of Section G (Botany) of the A. A. A. S. in 1924. He was president of this Society in 1923, having previously served as a member of the War Emergency Board (1918), chairman of the Advisory Board (1919–1921), representative to the National Research Council (1919–1922), and Secretary-Treasurer (1918–1922). In this last capacity especially he placed this Society under deep obligations to him for the efficiency of his methods and his sense of organization.

Dean Lyman was a remarkable executive of the type most needed at the present time—a harmonizer of conflicting interests. Few men have his capacity of appreciating the other man's point of view. Humorous, essentially friendly, free from cynicism, cheerful in the face of misfortune, he is sincerely mourned by a host of friends.

RICHARD CHAMBERS WALTON, 1886–1926

Richard Chambers Walton received the degree of Bachelor of Science from the Pennsylvania State College in 1911, and the degree of Master of Science in 1923. After graduation he was employed by the Pennsylvania Chestnut Blight Commission for about two and one-half years. In 1914 he went to the Ohio Agricultural Experiment Station as Assistant Botanist, where he was engaged for four years in the study of fruit diseases. When the Pennsylvania State College established a field laboratory in Adams County, Pennsylvania, in 1918, he was appointed plant pathologist in that station. Later he was promoted to the rank of Associate Professor. While connected with the Pennsylvania State College, he was concerned with the investigation of apple diseases giving special attention to frog-eye and blotch. Mr. Walton made a number of contributions to the science of plant pathology through his work in Ohio and Pennsylvania. He will be remembered by friends and associates for his excellent spirit of cooperation and for the fine enthusiasm toward his work which he maintained to the last.

HAROLD WAKEFIELD FITCH, 1897–1926

Harold Wakefield Fitch received the degree of Bachelor of Science from New Hampshire University in 1921. He had practically completed the requirements for the Doctorate of Cornell University, where he held the Herman Frasch Fellowship in Plant Pathology. At the date of his untimely death he was a member of the scientific staff of the Niagara Sprayer Company. In his chosen field of applied plant pathology he was a man of great promise.